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Luigi S. Cicolani, Ranjana Sahai, George E. Tucker, Allen H. McCoy, Peter H. Tyson, Mark B. Tischler, Aviv Rosen

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SUMMARY

Helicopter slung-load operations are common in both military and civil contexts. Helicopters and loads are often qualified for these operations by means of flight tests, which can be expensive and time consuming. There is significant potential to reduce such costs both through revisions in flight-test methods and by using validated simulation models. To these ends, flight tests were conducted at Moffett Field to demonstrate the identification of key dynamic parameters during flight tests (aircraft stability margins and handling-qualities parameters, and load pendulum stability), and to accumulate a data base for simulation development and validation. The test aircraft was a UH-60A Black Hawk, and the primary test load was an instrumented 8- by 6- by 6-ft cargo container. Tests were focused on the lateral and longitudinal axes, which are the axes most affected by the load pendulum modes in the frequency range of interest for handling qualities; tests were conducted at airspeeds from hover to 80 knots. Using telemetered data, the dynamic parameters were evaluated in near real time after each test airspeed and before clearing the aircraft to the next test point. These computations were completed in under 1 min. A simulation model was implemented by integrating an advanced model of the UH-60A aerodynamics, dynamic equations for the two-body slung-load system, and load static aerodynamics obtained from wind-tunnel measurements. Comparisons with flight data for the helicopter alone and with a slung load showed good overall agreement for all parameters and test points; however, unmodeled secondary dynamic losses around 2 Hz were found in the helicopter model and they resulted in conservative stability margin estimates.

INTRODUCTION

Helicopter slung-load operations are common in both military and civil contexts. The slung load adds load rigid-body modes, sling stretching, and load aerodynamics to the system dynamics, which can degrade system stability and handling qualities and reduce the operating envelope of the combined system below that of the helicopter alone.

Military helicopters and loads are often qualified for external load operations by means of flight tests. This includes certification of loads for the multiservice Helicopter External Air Transport (HEAT) manuals (ref. 1), in which pilots evaluate specific load-helicopter combinations for flying qualities and airspeed limits without analytical support and without generating quantitative stability data. There can also be extended tests, including analyses, to certify a helicopter's load-carrying capacity (ref. 2). However, such tests are expensive and time consuming. Further, stability and envelope limits can vary significantly among the large range of loads and slings that a utility helicopter will encounter in its operating life so that flight tests cannot practically encompass the entire operating range of configurations. As a result, the history of slung-load operations records numerous incidents and accidents in which the dynamic limits of the system were unknowingly exceeded (refs. 3, 4).

A 1994 industry paper advocated the accumulation of quantitative stability data from slung-load certification flight tests and pointed out the potentially significant reductions in cost and risk available from using a validated simulation to predict stability for a variety of sling-load combinations and to predict the critical cases for flight-test evaluation (ref. 2). Toward these objectives, an exploratory project was initiated at Ames in 1995 in which flight tests were conducted to identify aircraft stability and handling qualities and load-pendulum stability from telemetered data during the flight test. Stability evaluations were made after each test airspeed before going on to the next. Flight-time analysis has been used in several flight-test programs since the early 1980s to identify structural damping or stability margins from telemetered data, allowing completion of envelope clearance tests in hours or in a single flight instead of days or on multiple flights (refs. 5-7). Such a capability would have the potential to significantly reduce slung-load qualification tests in comparison to point-by-point test and analysis. A data base was also accumulated for subsequent simulation development and validation efforts.

This report describes the flight-test methods and results, and the simulation model and validation results. The test aircraft was a UH-60A Black Hawk. Test loads included a 1,000-lb steel plate, two steel block loads of 4,000 and 6,000 lb, and an 8- by 6- by 6-ft CONEX (CONtainer Express) cargo container which was flown empty (2,000 lb) and ballasted (4,000 lb). The plate was suspended with a 23-ft single cable and the remaining loads with a standard military 4-legged sling. The CONEX is a low-density load with significant aerodynamics and is limited to 60 knots in military operations owing to load stability limits (ref. 1). An instrumentation package was carried on the 4,000-lb block and the CONEX container which included accelerometers, angular rate sensors, and a fluxgate compass. The load instrumentation allowed computation of load-stability parameters during flight tests, and documented details of the load dynamics not previously available for simulation validation. Tests focused on the longitudinal and lateral axes in which the load-pendulum motions have their principal effects on aircraft control, and covered the frequency range of interest for handling qualities from 0.05 to 2 Hz. Tests were conducted at airspeeds between hover and 80 knots. Flight-time identification was performed with the CIFER® integrated package for frequency domain analysis (refs. 8, 9) operated through a special user interface designed for efficiency in the flight-test context.

The helicopter model used in the simulation was the Sikorsky GenHel blade-element model of the UH-60A (ref. 10) which was previously used and validated for handling qualities at Ames (refs. 11-13), as well as at Sikorsky (ref. 2). This helicopter model was integrated with the two-body dynamics of the helicopter-load-sling combination (ref. 14), a model of the rotor downwash field in the vicinity of the load, and a static aerodynamic model of the CONEX container obtained from wind-tunnel data (ref. 15). The validation was concerned mostly with lateral and longitudinal on-axis responses to control inputs over the frequency range of interest.

The work described here was conducted under the NASA Rotorcraft Program and as part of a U.S./Israel memorandum of agreement for cooperative research on rotorcraft aeromechanics and man-machine integration technology. Under this agreement the United States provided flight testing and data analysis and Israel provided the load instrumentation package and wind-tunnel testing of the CONEX container.

The report begins with a discussion of the parameters to be identified and the required computations, followed by a description of the test setup, the flight-time identification system and its performance, the flight-test results for frequency responses and parameter values, and the simulation validation results. Additional documentation can be found in references 16 and 17 for the test equipment and early test results; in references 18 and 19 for the flight-time identification system; and in references 20 and 21 for the simulation and its validation.

Many individuals made significant contributions to the conduct of these flight tests including the Ames test pilots and crew chiefs, the aircraft support crew and load handlers, the telemetry ground station group, the engineering design and test services groups and wind-tunnel and instrumentation personnel. Special mention should be made of Dan Levine, Ronit Yaffe (Technion), S.Sgt. Dani Marmar (Israel Air Force), Bruce Gallmeyer, Y. S. Ng, Mei Wei, Mitch Aoyagi, Ricky Simmons, Munro Dearing (NASA), and Zoltan Szoboszlay, Lt.Col. Chris Sullivan, Chris Blanken (U.S. Army) for their extended efforts and critical contributions.

KEY DYNAMIC PARAMETERS

Dynamic System

The dynamic system (fig. 1) consists of the helicopter and load. A stability augmentation system (SAS) is closed around this, and the pilot closes another loop around that combination to regulate the system to a desired flight path and to carry out tasks associated with the helicopter's mission. The plant element is rich in dynamics, including the helicopter's rigid-body modes, rotor modes, engine and drive-train modes, and structural modes. The load adds its rigid body and elastic sling modes to this set.

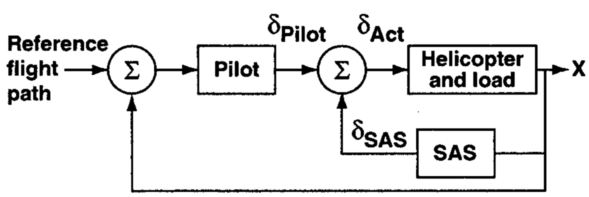


Figure 1. Dynamic system.

Over the years, the U.S. military has developed handling-qualities requirements that the closed-loop system must meet in order to provide satisfactory dynamics when the pilot exercises control to carry out the aircraft mission (ref. 22), and stability margins that the stability augmentation system must meet to avoid potentially destructive resonance with the plant dynamics (ref. 23). The clearance of loads is concerned with evaluating these handling qualities and stability margins for the combined system and the stability envelope of the load. Quantitative assessment of key stability and handling-qualities parameters for this study is based on frequency-domain analysis of the dynamic system.

Handling-Qualities Parameters

The handling-qualities parameters of interest are properties of the on-axis closed-loop roll and pitch-attitude frequency responses ϕ/δ_{LAT}, θ/δ_{LON} (generically x/δ_{PILOT} in fig. 1). Two primary parameters are bandwidth and phase delay (ref. 22). Bandwidth is the largest input frequency for which there is at least 6 dB of gain margin and 45° of phase margin; that is, it is the largest frequency the pilot can use and still maintain adequate margins from instability. Phase delay is a measure of the rate at which the phase changes at the frequency where the phase shift is 180°. Phase delay indicates how rapidly the pilot/vehicle closed-loop system is going unstable as the input frequency approaches the point of 180° phase shift. Larger values result in pilot complaints about a lack of predictability and a tendency for uncommanded oscillations in attitude or flight path.

The U.S. Army's Aeronautical Design Standard, ADS-33D contains specifications for handling qualities, including boundaries for the combination of bandwidth and phase delay for Level 1 (satisfactory), Level 2 (adequate), and Level 3 (unsatisfactory) handling qualities based on pilot rating data (ref. 22). ADS-33D includes requirements for other dynamic parameters, as well as the on-axis response parameters computed in this study. Although those specifications were defined for the scout attack mission and did not consider slung loads, the ADS-33D Levels 1-3 were adopted as the reference specifications for the present study.

Another Army project at Ames undertaken to extend ADS-33D to utility helicopters and slung-load operations was recently completed (ref. 24). The results of that study and results from references 25 and 26 have been used to extend ADS-33D to cargo and utility helicopters (ref. 27). The results from reference 24 regarding slung-load configurations will be discussed in a later section.

Stability Margins

Stability margins define the stability robustness of the aircraft-SAS feedback loop to changes in gain (gain margin) and phase (phase margin). Typical requirements from MIL-F-9490D (ref. 23) for production aircraft are that the "broken loop" response of the SAS signal to the inputs to the primary actuators ($\delta_{SAS}/\delta_{ACT}$ in fig. 1) have 6 dB of gain margin (a factor of 2) and 45° of phase margin. These requirements also ensure well damped responses to turbulence and pilot inputs. The UH-60A has roll, pitch, and yaw SAS channels, and stability margins can be computed for these channels. Phase margin is computed at the crossover frequency where gain crosses through 0 dB, and is the margin from –180° of phase shift there. The gain margin is the value of gain where the phase angle goes through –180°. There can be multiple crossings of 0 dB and –180°, in which case the margins are taken as the smallest for the crossings in the frequency range of interest for handling-qualities analysis, 0.05-2.0 Hz. The stiff airframe of the UH-60A precludes the potential for coupled structural/flight-control resonance at higher frequencies (above 2 Hz), and the critical stability margins occur in the handling-qualities frequency range. Large flexible helicopters like the MH-53J can have such resonance, and frequency sweep data are generated with tailored automated inputs and structural monitoring.

Load Pendulum Modes

Linear analysis indicates that the load adds a number of natural modes to those of the helicopter alone; these are two pendulum modes, two yaw roots (real or oscillatory, depending on load aerodynamics), and three oscillatory modes for sling vertical stretch and load pitch and roll attitude. Of these, only the pendulum modes interact with the helicopter in the frequency range of interest. Pendulum frequencies can be roughly estimated from a point-mass dumbbell approximation of the system as

$$\omega_p = \sqrt{\frac{g}{\ell}\left(1+\frac{W2}{W1}\right)}$$

where ℓ, W1, and W2 are the sling length and the load and helicopter weights, respectively. Pendulum frequencies between 1 and 2 rad/sec are estimated for the test configurations. (A more accurate approximation, which accounts for the effect of helicopter inertia, is given in ref. 20).

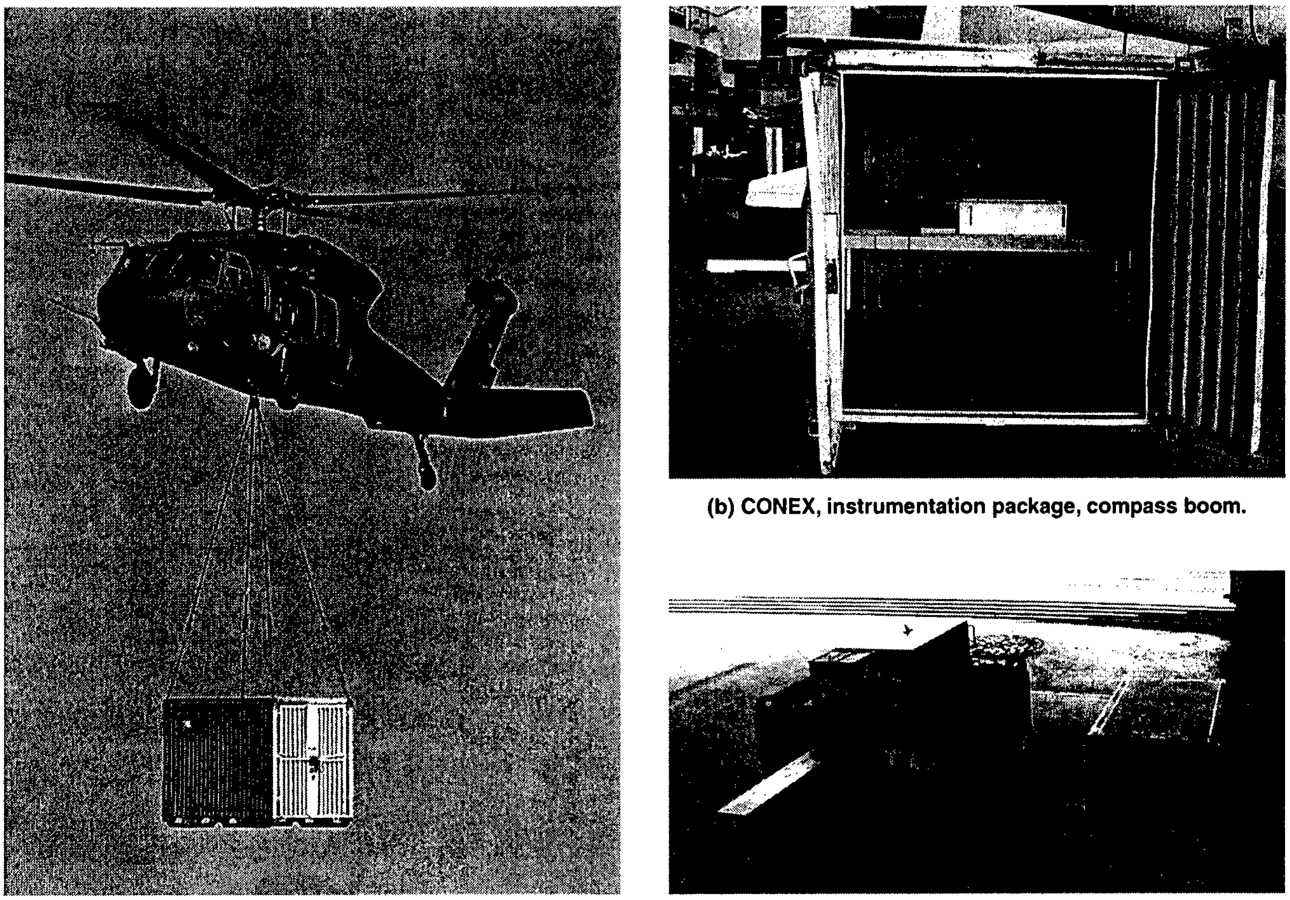
The pendulum modes at hover are decoupled lateral and longitudinal modes which are excited by lateral and longitudinal control inputs, respectively. Each mode can be identified by fitting a second-order transfer function to the frequency response of the load angular rate in the region around the pendulum frequency.

FLIGHT TEST SETUP AND PRELIMINARY EVALUATIONS

Test Configurations

Slung-load configurations can be viewed as two rigid bodies connected by a sling, and defined by all the fixed parameters of the helicopter, load, and sling for which numerical values are required in the system's equations of motion. These parameters have a more or less important role which can be studied in simulations or with linear analysis. Out of the existing range of such configurations, the present tests are limited to a utility helicopter and a small sample of loads and slings rigged to a single-point suspension, but this suffices for the present objectives. Linear analysis for single and multi-cable slings indicates that the primary parameters affecting load motions are as follows. The load pendulum frequencies are set by sling length, load weight, and helicopter inertias, whereas helicopter c.g.-to-hook offset couples the load motions to the helicopter attitude dynamics which then are a source of pendulum damping in accordance with helicopter aerodynamics and inertias. Load aerodynamics increase with airspeed and have an increasing effect on load dynamics depending on the magnitude of the specific forces and moments produced.

Flight tests were performed with an instrumented UH-60A and with the test external loads and slings shown in figures 2 and 3. These included a CONEX cargo container, a 4,000-lb steel block, a 6,000-lb load made up of several steel blocks, and a 1,000-lb steel plate. The plate was suspended with a single cable and bridle, and the remaining loads with a standard military 4-legged sling.



(b) CONEX, instrumentation package, compass boom.

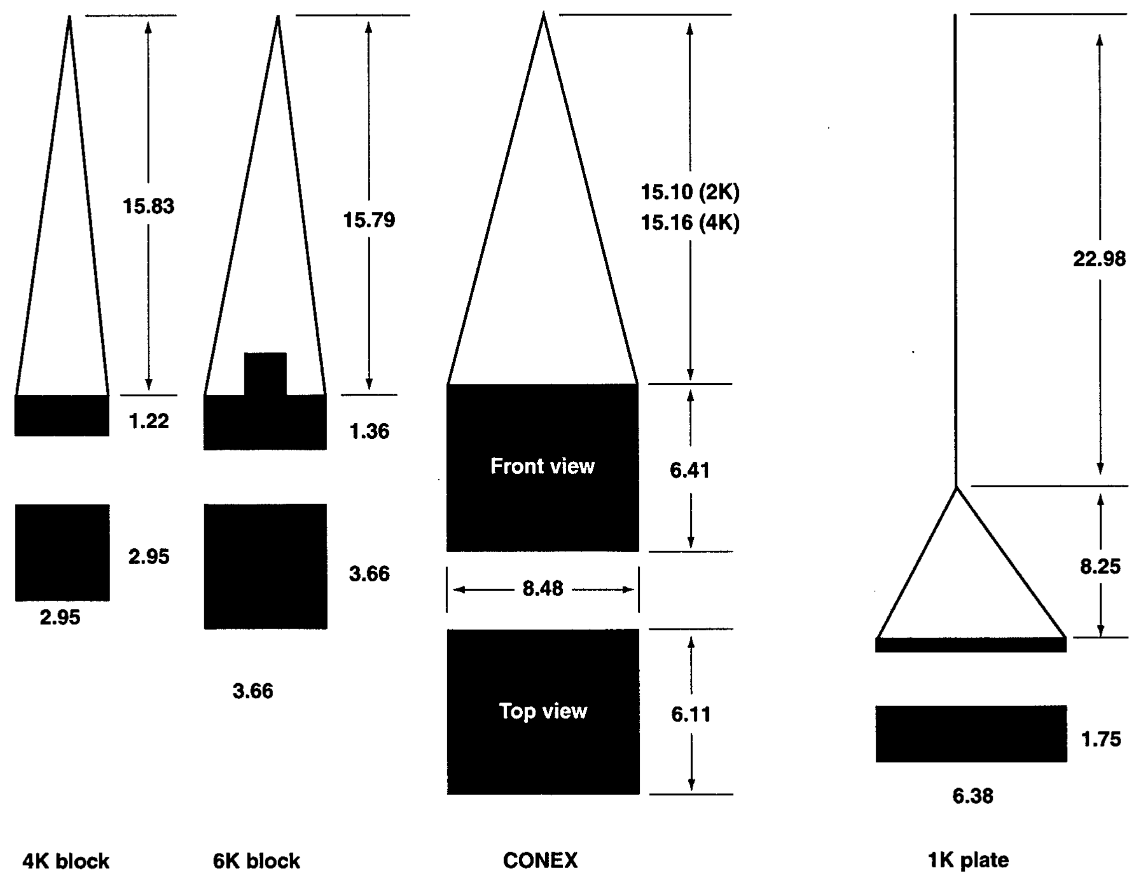
(a) Test configuration with CONEX.

(c) 4,000-lb block, instrumentation package, compass boom.

Figure 2. Slung-load configuration and load instrumentation.

Helicopter–The normal aircraft takeoff gross weight for slung-load operations is 14,600-lb, including two pilots, a crew chief, research instrumentation, and takeoff fuel. Approximately 1,800 lb of fuel (2 hr of flight) is available for use during a test, with corresponding changes in gross weight and with forward movement of the c.g. by 9 inches. Aerodynamic and other data for the UH-60A can be found in references 10 and 28-30.

The UH-60A hook is mounted in the floor of the helicopter and can be released manually at the hook or electronically from the right-seat stick. It is gimbaled only in roll so that the load-sling combination swings laterally about this axis, and longitudinally at the hook load beam about 8 inches lower. The hook is offset 4.3 ft below the aircraft c.g. and up to 1 ft forward of the c.g., depending on fuel weight, and is rated at 8,000-lb carrying capacity.



Units: ft, lbs, sec

	1K plate	4K block	6K block	Empty CONEX	Ballasted CONEX
Weight	1130	3895	6384	1794	4105
Density	456	391	315	5.4	12.5
Ixx	108	104	308	785	1876
Iyy	212	104	296	569	1482
Izz	121	174	471	766	1377

Figure 3. Load-sling test configurations: units–ft, lb, sec.

Loads and slings–Flight-test data were obtained for the aircraft alone and with the load-sling combinations noted above. The dimensions and mass-inertia data for these loads are included in figure 3. Load weights ranged from 1,000 to 6,000 lb (up to 41% of helicopter takeoff weight). The CONEX weight was varied by ballasting it with bags of loose material of density 43 lb/ft^3. It was flown empty at about 2,000 lb and ballasted at 4,000 lb.

The test loads other than the plate were suspended with a standard military four-legged sling set rated at 10,000 lb and weighing 52 lb. Each leg of this sling was 15.83 ft long unloaded. Sling

stretching was measured at 0.8 ft for the heaviest test load, and stretching frequencies are well above the range of interest for handling qualities. The HEAT manual provides details of the sling hardware and construction, and specifies the method of rigging this sling to standard loads such as the CONEX (ref. 1). More generally, the military inventory includes single-cable slings from 3 to 140 ft, and multi-cable slings rated to 40,000 lb which can be rigged with two to six legs, depending on the load (ref. 1). This sling was flown in the present tests with and without a swivel, which, for the CONEX, resulted in periodic or steady yaw rates depending on the presence of the swivel.

In preliminary flight evaluations the blocks were well-behaved out to the power-limited level flight speed of the aircraft (about 140 knots). These are very dense loads which generate little aerodynamic specific force over this speed range. The CONEX is a 6- by 6- by 8-ft steel container with corrugated sides and 6-inch skids along the long dimension. It is much less dense (5-12 lb/ft^3 average density in the present tests) with substantial aerodynamics that limit its envelope to 60 knots in military operations (ref. 1). However, the critical speed varies with load weight, and the CONEX was flown out to 70 knots IAS when ballasted without encountering the onset of instability. The effects of its aerodynamics included a load trail angle in proportion to the drag specific force, and yaw rotations of the load. These rotations began in hover owing to the downwash rotational field, and increased beyond 100 deg/sec above 50 knots airspeed. More generally, load aerodynamics can couple the yaw degree of freedom with the load pendulum motions as instability is approached, but the high yaw rates of the CONEX appeared to prevent coupling of these degrees of freedom in the present tests.

Instrumentation and Signals

Sensors–The test aircraft was heavily instrumented for an earlier air-loads study at Ames, as described in reference 31. The sensors recorded for the slung-load tests were those measuring the aircraft rigid-body states (accelerometers, rate and attitude gyros, air data, alpha-beta vanes, radar altimeter) and control deflections (stick positions, SAS outputs, mixer inputs, primary servo positions) with telemetry and recording rates of 209 Hz. Further, the hook was instrumented with a strain gauge load weight cell, and a video camera mounted in the hook hole recorded load motions relative to the aircraft.

A portable load instrumentation package weighing about 100 lb and costing approximately $40,000 was assembled for these tests (ref. 32). It contained three-axis accelerometers and rate gyros along with a power supply, filters, a PCM encoder, and a telemetry transmitter with output rates of 260 Hz. In addition, a gimbaled magnetic fluxgate compass was mounted on an aluminum boom extending 2.5 ft from the load to minimize magnetic interference. The instrumentation package is shown in figure 2 mounted on a support rail at midheight in the CONEX and on the surface of the 4,000-lb block. The compass boom can be seen mounted on the sides of these loads.

This sensor set suffices for the identification of the dynamic parameters, which require only the helicopter and load angular rates and heading, and the control positions. Important limitations were the lack of sensors for load attitude and translational velocity, and the hook force, which could be used to extract load aerodynamics from the flight data and for more detailed simulation validation of the load dynamics. In addition, the load instrumentation did not cover the unanticipated large yaw

rates of the CONEX load, which, at higher airspeeds, saturated the 120-deg/sec limit of the yaw rate gyro and induced large dynamic lags in the fluxgate compass signal. Nevertheless, the sensors provided good access to the load dynamics for the block loads at all test speeds, and for the CONEX up to 50 knots.

Signals–The helicopter sensors of principal interest are the angular rate and heading gyros. The rate signals typically contain a moderate amount of vibration at 2-3 deg/sec and at frequencies of 1-4 per rotor revolution, plus significant biases. Vibrations are well above and biases are well below the frequency range for the identification computations and have no effect on the frequency responses in this range. Initially the research directional gyro was not slaved and had a random startup bias and drift. This was replaced by a slaved gyro for the final set of tests.

The load signals from a lateral frequency sweep with the CONEX are shown in figure 4. The lateral pendulum is excited by inputs in the neighborhood of the pendulum frequency. The vertical accelerometer contains the centrifugal acceleration of the load pendulum swinging, which can be seen in figure 4 in the interval of 60-80 sec. The low-frequency variations in the x, y accelerometers in this record (taken at 30 knots) are the signature of the steady load trail angle owing to load drag combined with load yaw motions which distribute the specific drag to the x and y accelerometers according to the yaw time-history. For a simple pendulum, the apparent gravity is aligned with the cable direction during pendulum swinging in the absence of load aerodynamic force. In this case, the x, y accelerometer outputs are zero and the z accelerometer measures the hook force, assuming the z accelerometer is aligned with the cable direction. Aerodynamic force results in misalignment of the apparent gravity and the cable direction so that the x, y accelerometers measure the x, y aerodynamic force components, assuming again that the z accelerometer is aligned with the cable direction. For multi-cable slings, the line segment from hook to load c.g. is analogous to the cable direction of a simple pendulum and a similar argument can be traced concerning the accelerometer signals.

The yaw and yaw rate histories in this record indicate periodic yawing of the load during which the (unswiveled) sling wound up on itself and unwound. At airspeeds above 50 knots, the sling was seen in video recordings to wind up as many as 8-10 turns. The yaw motion is driven by the CONEX aerodynamics and, for the unswiveled attachment, this was countered by yaw resistance at the hook. The pitch and roll rate histories in figure 4 represent the angular velocity associated with load lateral pendulum motions which is distributed to the load pitch and roll rate sensors according to the load yaw history.

Signal Processing–Relatively little processing of the received signals was required for the identification computations. The helicopter stability margins and handling-qualities parameters were computed from the helicopter control and angular velocity signals with nothing more than scaling of the control signals. Computation of the load-pendulum roots required transformation of the load pitch and roll rate signals to axes aligned with the helicopter heading (p2', q2' in fig. 5) in order to obtain angular rates that measure swinging of the load c.g.. The transformed signals for the lateral sweep record in figure 4 are included in figure 5, and show that the load angular rates for this sample resolve mainly into roll rotation about an axis aligned with helicopter heading. In the early flights

with the CONEX, the first and last records of each flight were used to determine the bias of the unslaved helicopter heading gyro for these computations.

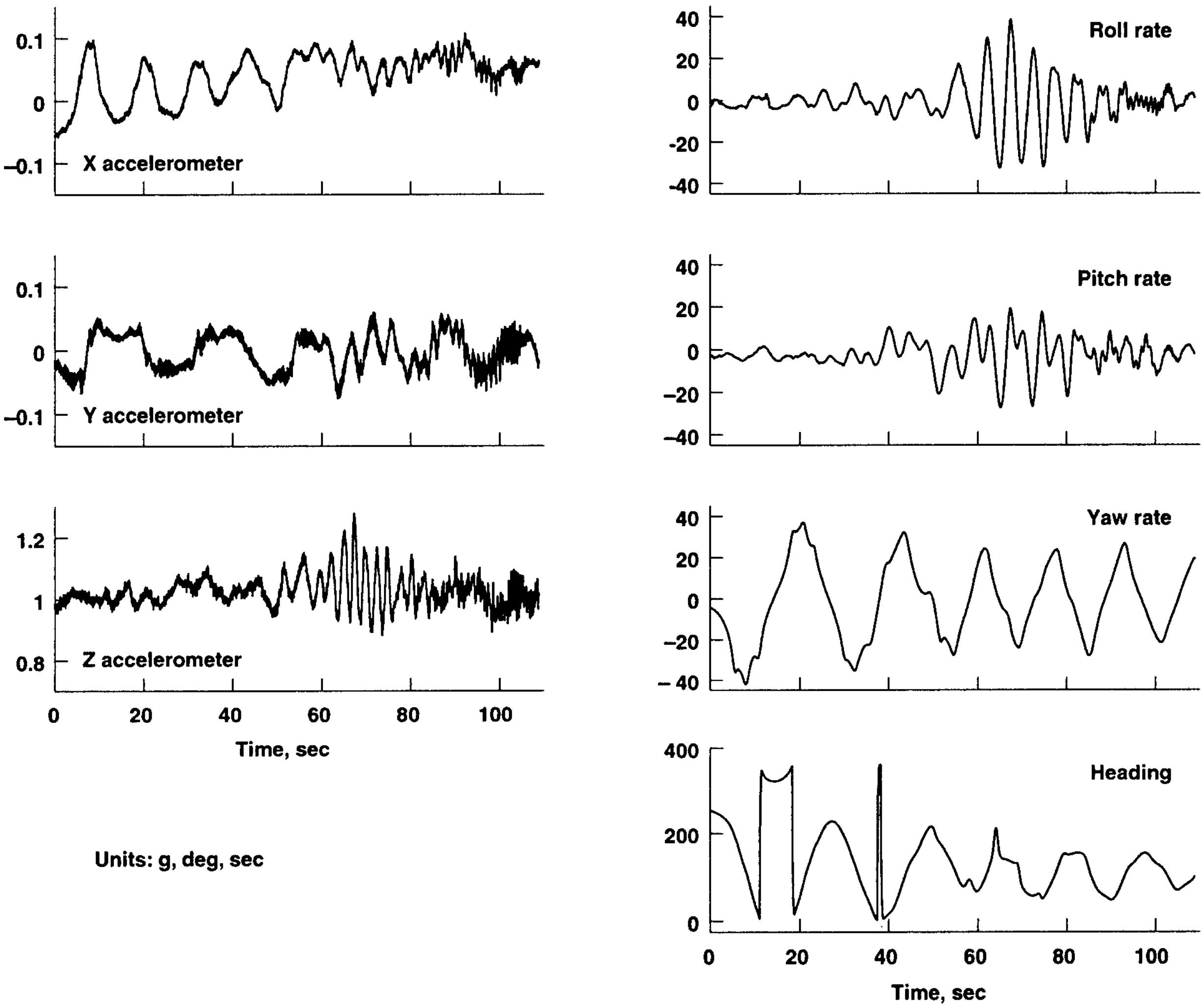


Figure 4. Load sensor signals: 30 knots, lateral sweep, 4,000-lb CONEX load.

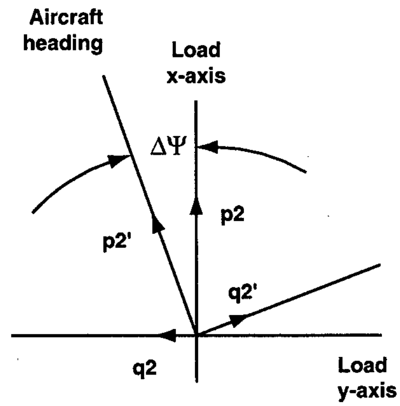
Flight Test Profile

Two procedures were used to attach the external load to the helicopter. In the early flights, the CONEX hookup was carried out by two load handlers atop the load (ref. 17). The helicopter approached and stabilized overhead for the hookup, with guidance from the crew chief. The rotor wake carried a significant amount of debris which buffeted the handlers during the approach, but this lessened when the helicopter was directly overhead. In the later flights, load hookup was effected by the "self hook" procedure. The aircraft taxied up beside the load, which had been prepared on the

ramp with the sling laid out lateral to the load, including an extension line if required. The crew chief then reached down through the hook hatch to pick up the hook or extension line and drew in the sling apex clevis and engaged it. The procedure was attended by a ground director and a safety monitor until the load was airborne. During the flight, the crew chief continually monitored the load for swinging in excess of a 30° safety limit.

$$\Delta\psi \equiv \psi_2 - \psi_1$$

$$\begin{pmatrix} p2' \\ q2' \end{pmatrix} = \begin{bmatrix} \cos\Delta\psi & -\sin\Delta\psi \\ \sin\Delta\psi & \cos\Delta\psi \end{bmatrix} \begin{pmatrix} p2 \\ q2 \end{pmatrix}$$



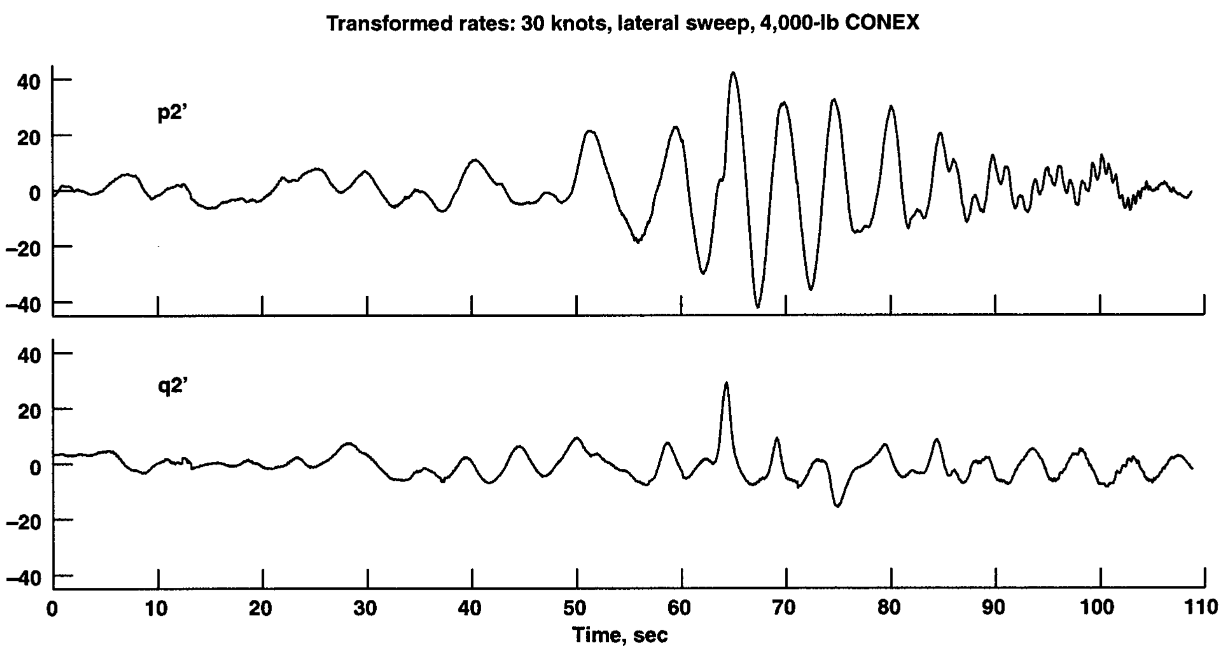


Figure 5. Transformed load angle rates (units: deg/sec).

Flight data were taken with the stability augmentation system (SAS) on and flight-path stabilization system (FPS) off. Otherwise the FPS would superpose control inputs on those of the pilot.

Data records at each flight condition consisted of a trim record, followed by three repeated frequency-sweep records, and ended with a pair of doublets in opposite directions with sufficient record length to capture the lightly damped pendulum modes. The identification computations used only the frequency-sweep records, and the doublets were recorded for time-domain confirmations. This sequence was performed chiefly with the longitudinal and lateral controls and at hover and at speeds of 30, 50, and 80 knots. A total of 19 data flights (20 flight hours) were flown during 1995-97 and 1999 at Moffett Field in calm winds. The flight records are archived electronically at Ames and a compendium of these records is provided in the appendix.

Frequency sweeps–Identification based on frequency-sweep flight-test data has been developed over the past decade, and numerous examples have been reported in the literature. The design and execution of pilot-generated frequency-sweep inputs has been considered in detail in reference 33 and 34. The main considerations in generating good data are to remain centered about the reference trim flight condition, and to avoid large correlated secondary control inputs, gust disturbances, control saturation, and excessive excitation of lightly damped modes in the frequency range of the test. Each aircraft and test-frequency range has its own unique considerations, but the UH-60A at forcing frequencies to 2 Hz presented no special problems.

A sample lateral axis control sweep is shown in figure 6. The pilot varied the forcing frequency smoothly over the range of interest for handling qualities, 0.05-2 Hz, beginning and ending with a short period of trim. The pilot used reduced amplitude at low frequencies to avoid the large excursions in helicopter attitude associated with low-frequency inputs, held amplitude to 1-1.5 inches (10-15% of control range) at mid-frequencies to avoid control saturation, and was careful to stop the sweep at 2 Hz to avoid resonance with the lowest frequency rotor and structural modes. The complete record was about 90 sec long. Test engineers assisted with timing and frequency monitoring during the sweep. The pilot tried to maintain the reference conditions with occasional uncorrelated low-frequency off-axis inputs, and the off-axis controls and the pitch and yaw attitude departed very little from their trim values, as seen in figure 6. Generally, airspeed variations up to 10 knots around the reference speed can be tolerated without significant loss of linearity, and excursions of this size were common away from hover. Helicopter roll rate tracked the control history out to around 1 Hz (fig. 6), with amplitude up to 15 deg/sec around the mean; the transformed load roll rate, p2', responded principally to control inputs in the neighborhood of the pendulum frequency (about 0.25 Hz) with peak amplitude of 20 deg/sec.

Data Acquisition and Flight-Time Identification

Data acquisition–The data acquisition system is shown in figure 7. All sensor signals were recorded on board the aircraft and telemetered simultaneously to the ground station, which was equipped for real-time strip-chart displays, data recording, and video monitoring of the aircraft when within camera range. The on-board load video was also recorded, but attempts to transmit it to a ground station monitor were only marginally successful. In addition, a server-client system provided data communications from the real-time telemetry receivers to a system of three workstations where the flight-time computations were performed. Data were input to the workstations using an on-off switch which allowed the test engineer to store and concatenate the three frequency-sweep records obtained at each test condition. These workstations were slow (36 MHz) compared to current

workstations (200-500 MHz). The ground station and telemetry support was provided by Dryden's Western Aeronautical Test Range facility resident at Moffett Field. Details of the server-client system are reported in reference 18.

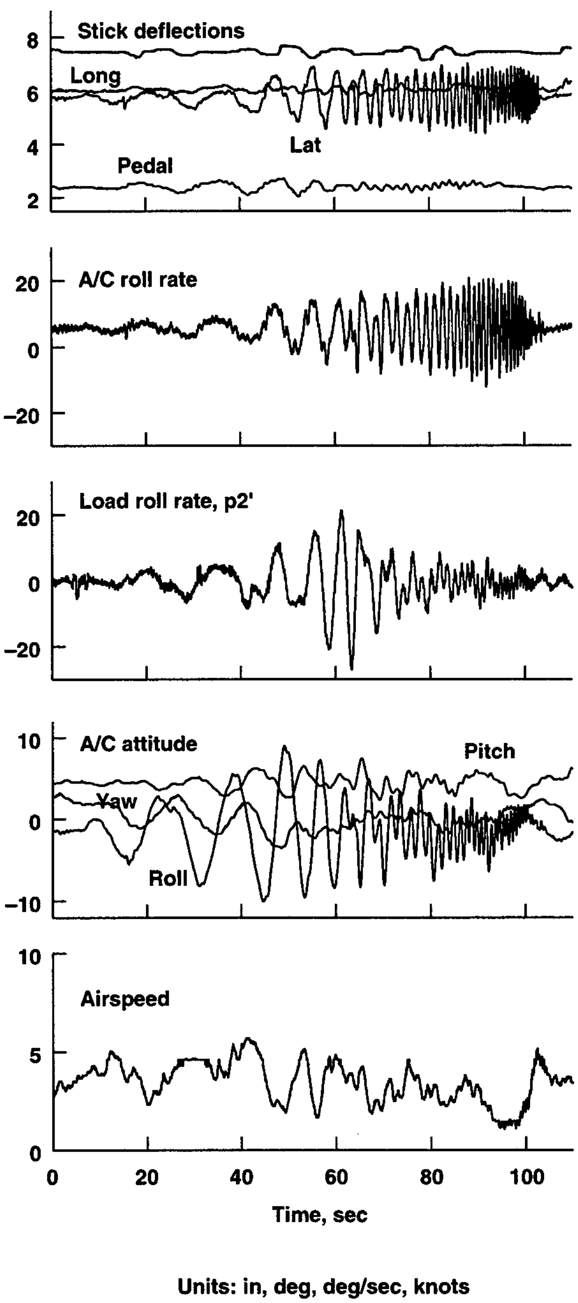


Figure 6. Sample frequency sweep: hover, lateral sweep, 4,000-lb CONEX load.

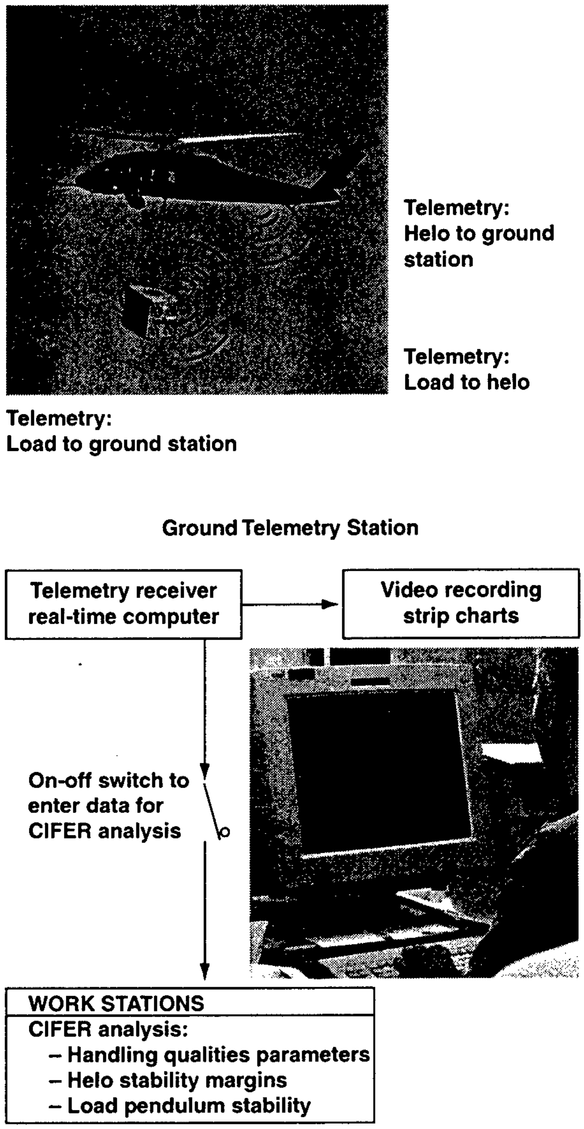


Figure 7. Data acquisition and flight-time analysis system.

Identification computations–The required computations were carried out using the CIFER® software for interactive frequency-domain analysis (refs. 8, 9). CIFER® provides a comprehensive set of utilities for aeronautical applications and has received wide application in the past decade to both helicopters and fixed-wing aircraft.

Frequency-response functions between input and output flight records are determined for the frequency-domain identification. These responses represent the first harmonic approximation of the nonlinear plant dynamics. The residual signal associated with the higher-order harmonics is seen as noise in this procedure. The quality of this approximation is measured by the coherence function, γ^2, which is the linear correlation between input and output as a function of frequency and has values in

the interval [0, 1] (ref. 35). Turbulence, measurement errors, correlated off-axis inputs, and nonlinear dynamics reduce coherence. An objective of the computations is to maintain adequate coherence ($\gamma^2 > 0.6$) at all frequencies in the frequency range of interest, and there are numerous devices aimed at doing this, both in generating the flight data and in the computational procedure (ref 9).

The CIFER® computational steps in the slung-load identification are outlined in figure 8. First, the available frequency-sweep records are concatenated so as to maximize the information for the flight condition. Second, the single-input-single-output Bode plots are computed for one or more selected "window" sizes. The concatenated record is divided into overlapping time intervals, or windows, for these computations and the final frequency responses are obtained as averages of the results from these windows. Window size determines the lowest frequency for which the frequency response can be given and the frequency range in which coherence is optimized. Multiple window sizes can be used and combined to optimize the resulting coherence over the range of interest. Third, correlation of the responses with off-axis inputs is removed to yield conditional responses. Fourth, the multi-window optimization is performed. Finally, the handling-qualities parameters and stability margins are computed using the CIFER® Bode plot analysis utility, and the load pendulum roots are determined by fitting a second-order pole to the load's frequency response in the neighborhood of the pendulum frequency using CIFER®'s fitting utility.

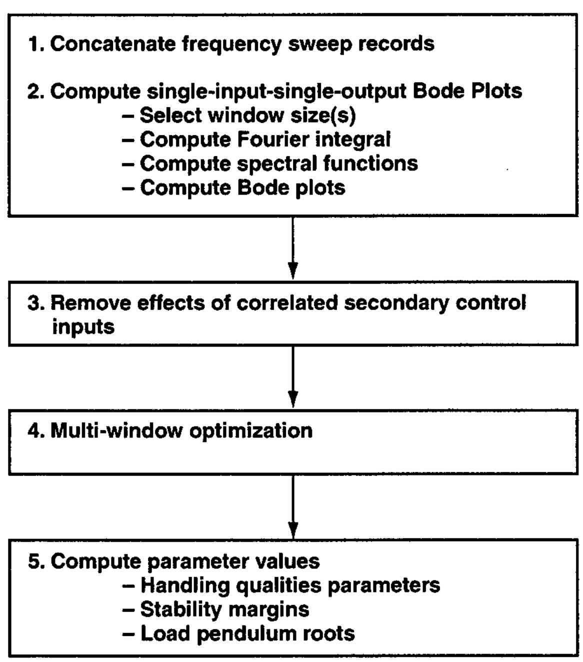


Figure 8. Identification procedure.

Flight-time identification and user interface–Execution time is a factor of interest in the flight-test context. The computation time and accuracy of the procedure depend on several factors, including data rate, number of windows, conditional response computations, and data dropouts in the records. Postflight analysis used data at 100 Hz, five windows (10, 20, 25, 30, and 40 sec), and on-board data recordings which were normally free of data dropouts. In addition, execution time depends on user interface efficiency.

The flight-time procedure for the 1997 flights used the existing CIFER® user interface which required numerous screens and keyboard inputs to carry out the above procedure (ref. 16). Consequently, computation time reductions were important. The flight-time procedure used data decimated to 50 Hz and a single window (20 sec). The 50-Hz data rate satisfies the working rule of 16 times the highest frequency of interest. Computation time increases significantly with the number of windows, so a single 20-sec window was used; it provided frequency responses down to 0.05 Hz. The effects of correlation with off-axis inputs were found to be small in nearly all cases so the time-consuming computations required for their removal were dropped from the flight-time procedure. The inevitable wild points and momentary dropouts in telemetered data were seen as high-frequency noise in the frequency-domain analysis and usually had no significant effect on data quality. Extended dropouts owing to antenna shadowing occurred sometimes, depending on aircraft heading, but these were apparent on the strip charts, and the test record was repeated immediately. This system gave satisfactory accuracy in matching postflight results, and the entire identification procedure took an average of 4 min from the completion of the last frequency-sweep record to the appearance of frequency responses and parameter values on screen. This was a little longer than it took for the pilots to complete the doublets and to be ready for the next test point. The main problem was the excessive repetitive inputs of the user interface and its error-proneness in the flight-test context.

A graphical user interface was designed to address this problem and was demonstrated during the 1999 flights. The interface consists of a split screen (fig. 9) with keyboard and point/click inputs. The top left subscreen is used to enter the case (case name, control axis, record numbers to be processed, window sizes). The lower left subscreen changes with the computations to be performed (handling qualities, stability margins, or load modes) and provides for entry of basic parameters associated with each type of computation. The right screen provides for display and printout of numerical and graphical results. The time saved on input overhead was used in part to allow two windows in the computations. The resulting system required 3.5 min on the 36-MHz workstations, and the results closely matched those of the postflight computations in all cases. The same procedure on a readily available 195-MHz machine was found to require only 40 sec, which fits the flight-test pace very well. The flight-time identification system is discussed in greater detail in reference 19, and the user interface is available for UNIX machines with the CIFER® license.

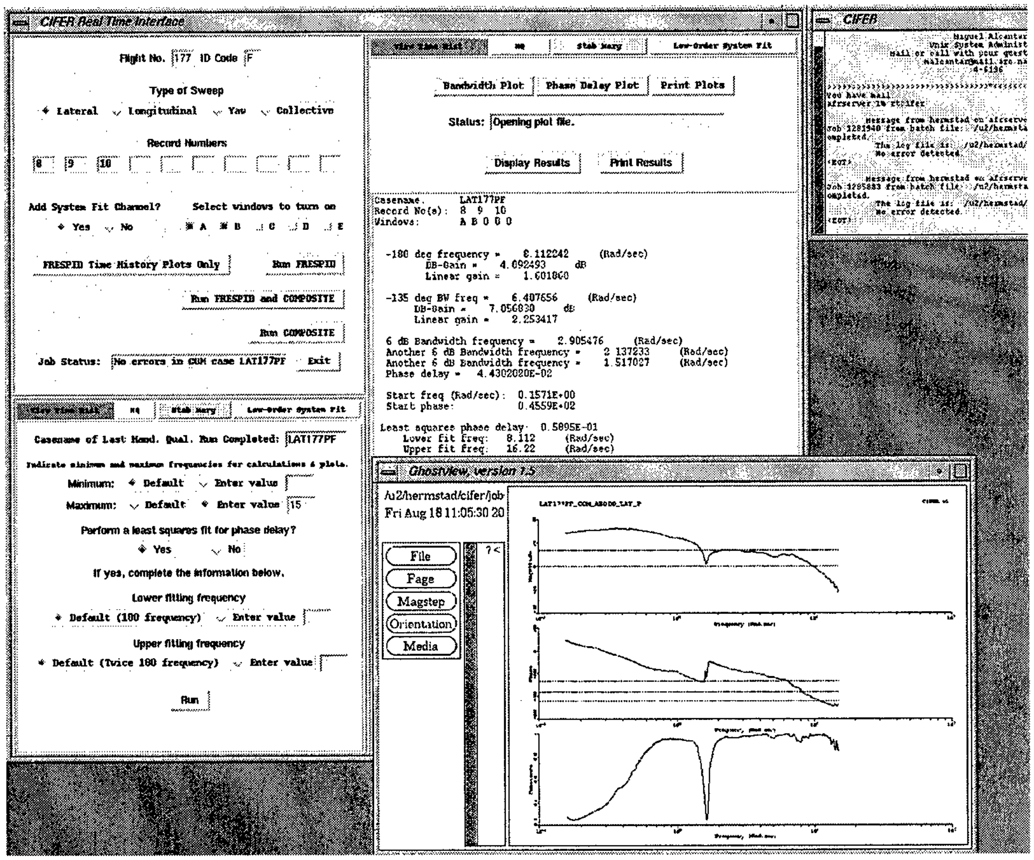


Figure 9. Graphical user interface for CIFER®.

FLIGHT TEST RESULTS

Handling Qualities

The detailed effects of the load on the attitude responses ϕ/δ_{LAT}, θ/δ_{LON} are seen in figure 10, which compares hover responses for no load and for block loads. The no-load response is that of the rigid-body dynamics (approximately

$$\frac{\phi}{\delta_{LAT}} = \frac{L_{\delta LAT}}{s(s - L_p)}$$

for the lateral axis) out to 1 Hz. The load introduces a pole-zero combination at the pendulum frequency. For the lateral axis (fig. 10(a)) this reduces gain near the pendulum frequency (at about 1.5 rad/sec), increases phase shift at frequencies below the pendulum frequency, decreases phase shift above the pendulum frequency, and reduces coherence at the pendulum frequency. These effects reflect excitation of the load pendulum modes by cyclic inputs in this frequency range (shown in a later figure) and a corresponding loss of helicopter response. These effects increase with load weight. The load effects on the gain curve can move the gain margin bandwidth below the pendulum frequency as in the figure, or result in multiple values below and above the pendulum

frequency, thereby reducing the attitude bandwidth of the system significantly. The effects of the load on the longitudinal responses (fig. 10(b)) are much reduced compared to the lateral axis. This is because of the much larger helicopter pitch inertia (by a factor of 7) which reduces coupling of the load longitudinal pendulum motions with the helicopter pitch-attitude dynamics. Physically, the specific moments of the load on the helicopter are proportional to the hook-to-c.g. offset and inversely proportional to inertia.

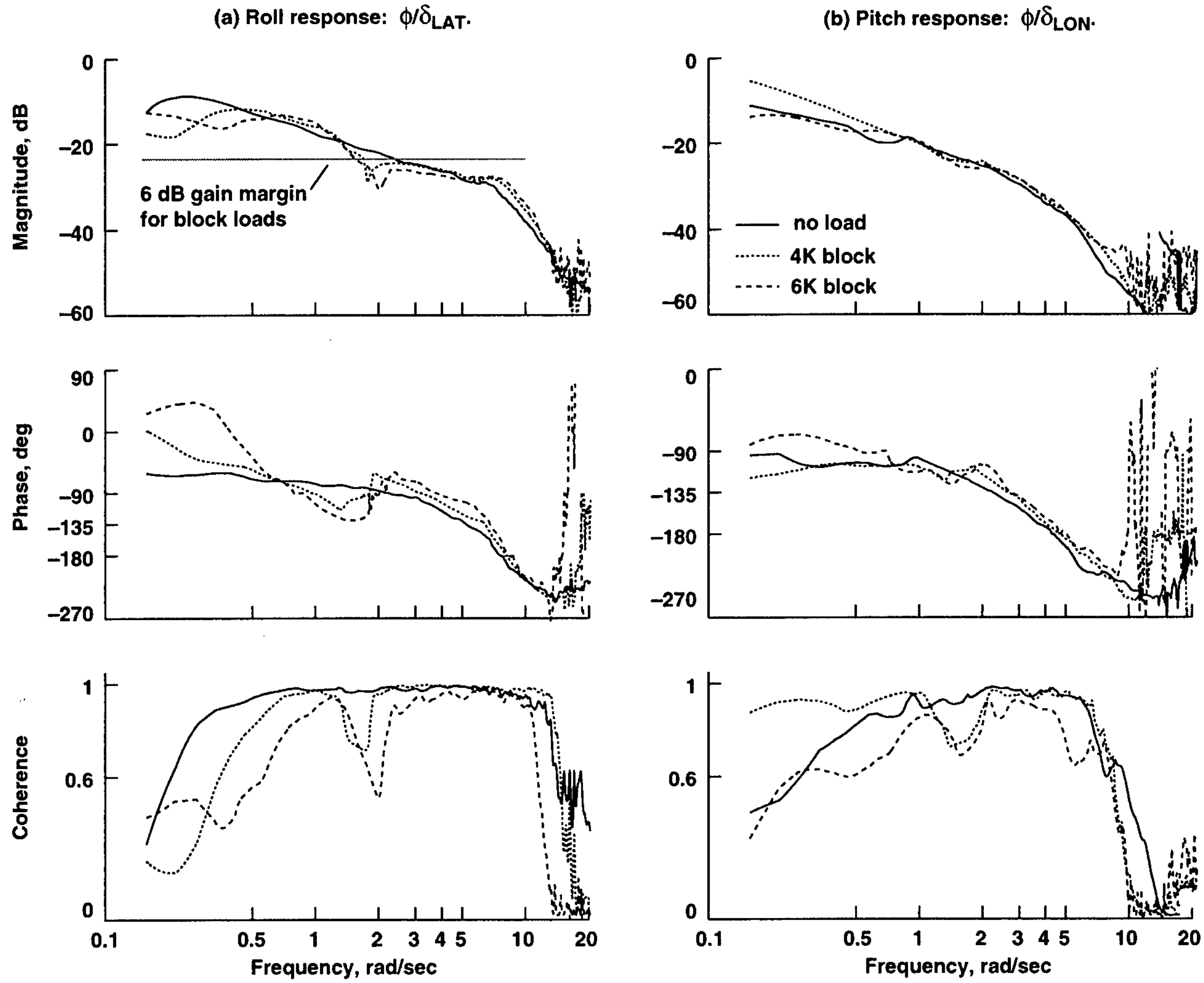


Figure 10. Effect of load on attitude frequency response – hover.

Results for the handling-qualities parameters are shown in figure 11 versus airspeed. In cases of multiple bandwidth values, the highest and lowest values are shown. For the lateral axis there is a significant loss of bandwidth because of the load at hover, and some differences among loads of the

same weight. At forward speeds there are multiple values of bandwidth with the lower value below 2 rad/sec. The longitudinal axis shows an increase in bandwidth owing to the load at all speeds.

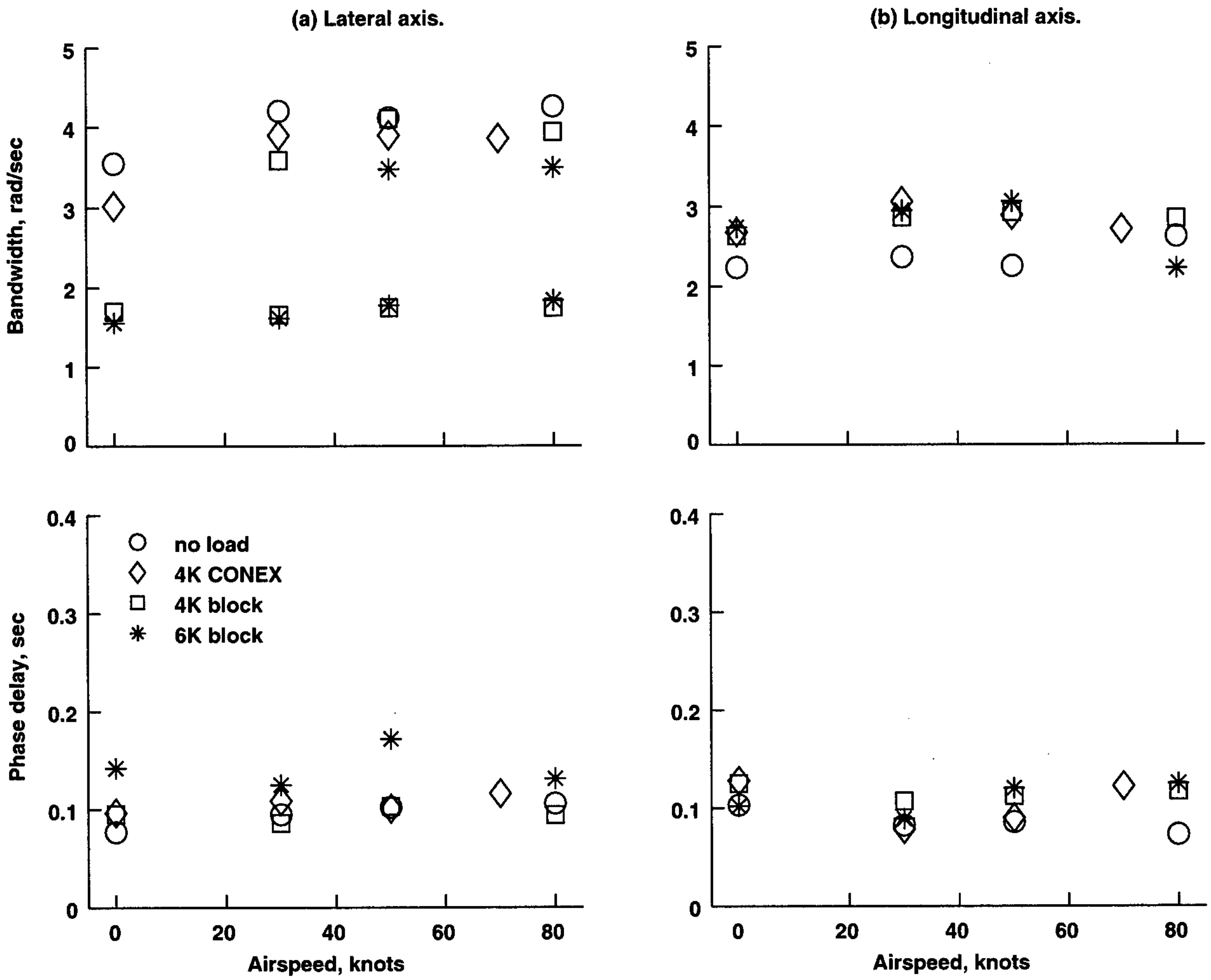


Figure 11. Handling-qualities parameters versus airspeed.

The lateral axis results are shown in figure 12 in a plot of phase delay versus bandwidth. The plot includes the ADS-33 Levels 1-3 boundaries for reference. Level 1 requires a bandwidth of 2 rad/sec or higher, depending on the phase delay. There is a general loss of attitude bandwidth for all loads, and an apparent loss of handling qualities to Level 2 for the block loads when measured against the no-load boundaries. However, the ADS-33 boundaries were established to predict handling-qualities ratings for scout-attack helicopters and may not predict handling-qualities ratings for slung-load configurations. It is beyond the present scope to establish new measures for quantitative evaluation of slung-load handling qualities, but a recent study of this issue at Ames on a moving-base simulation of the CH-47D should be noted. Several hover/low-speed tasks with potential excitation

of load motions (precision hover, lateral reposition, normal depart/abort) were evaluated. No correlation of pilot ratings with attitude-control bandwidth for the helicopter-load combination was found. The main issue was whether the pilot could supply sufficient gain for precise aircraft and load control without driving either the aircraft or load dynamics unstable, which is related to translational control. Results showed a linear loss of handling-qualities ratings with increasing load weight, and a degradation to Level 2 handling qualities for weight ratios, W_{LOAD}/W_{TOTAL}, at and above 33%. Further, the study found correlation of pilot ratings with bandwidth and helicopter-load coupling parameters computed from the closed-loop translational velocity response, and criteria for these parameters were proposed in reference 36.

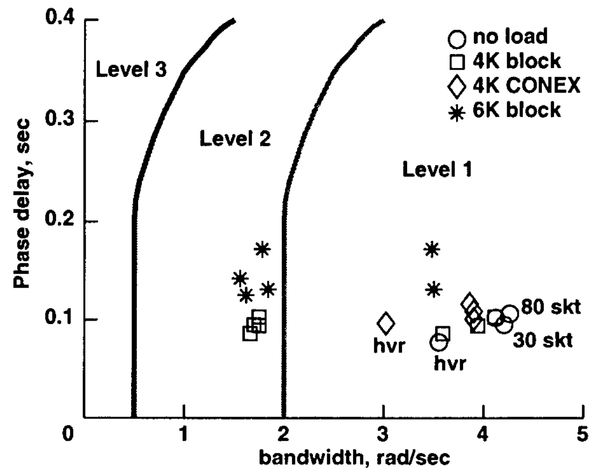


Figure 12. Lateral axis handling-qualities parameters.

Flight tests were conducted at Ames during 1999 to extend ADS-33D to utility helicopters and slung loads. A variety of tasks were defined and tailored to the utility helicopter mission, and pilot opinion ratings were obtained and reported in reference 24. Results from that study for maneuvers with potential to excite the pendulum modes (hover acquisition, pirouette, lateral reposition, normal depart and abort, and slalom) are shown in figure 13 for the 6,000-lb block load (weight ratio at and above 30%) and for no slung load (with internal ballast to approximately match total weight). These results show little evidence of degraded pilot ratings owing to the load for the near-hover tasks despite the loss of attitude-control bandwidth computed above. The results of the slalom task show a loss of ratings owing to difficulty in anticipating load-swinging motion to control the aircraft flight path around the course pylons. The new standard, ADS-33E, evaluates slung-load handling qualities based solely on qualitative pilot ratings and does not establish any quantitative specifications (ref. 27).

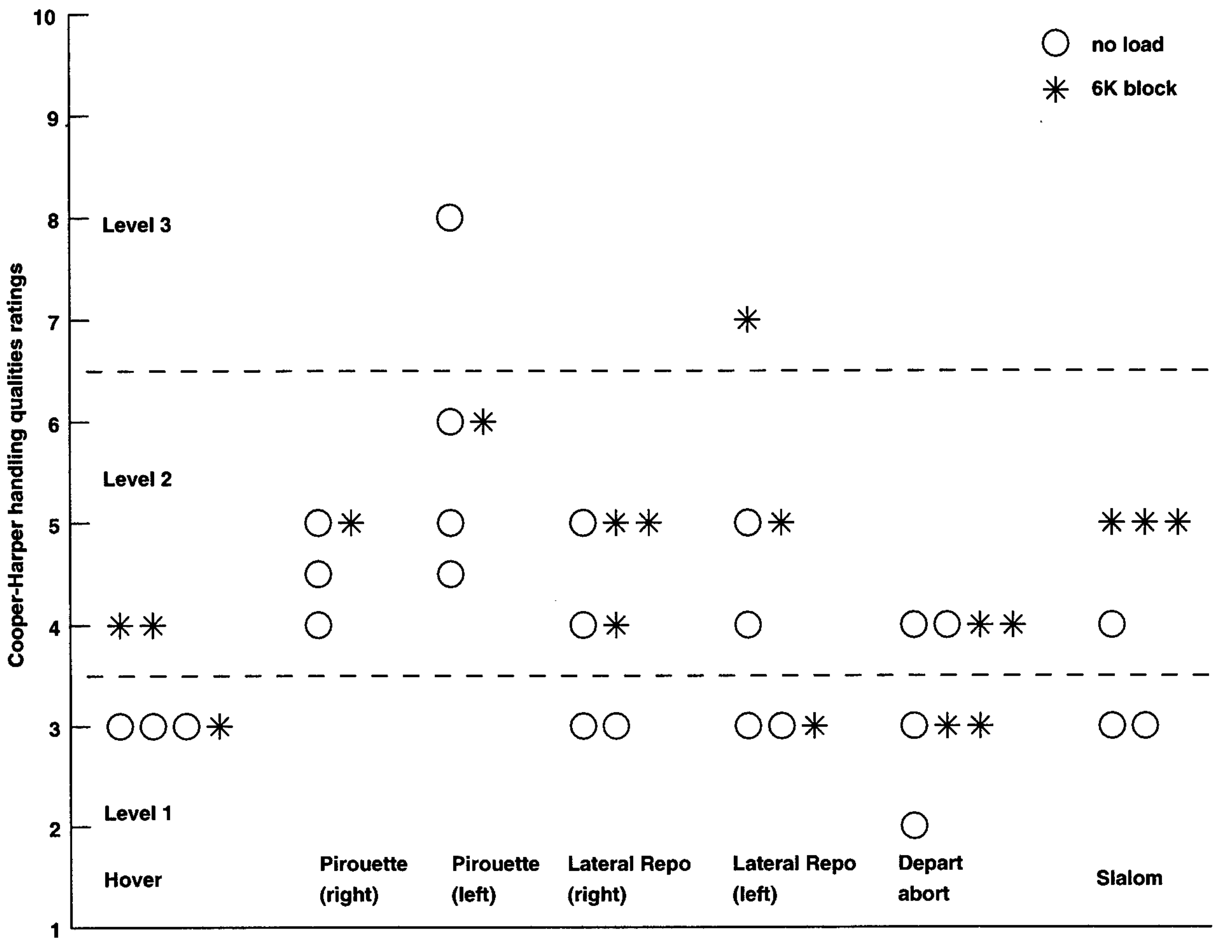


Figure 13. Pilot ratings.

Control System Stability Margins

The detailed effects of load weight on the stability loop response ($\delta_{SAS}/\delta_{ACT}$ in figure 1) are shown in figure 14. The effect of the load on the lateral axis gain and phase curves is similar to that previously seen for the closed-loop roll response; that is, a gain dip occurs around the pendulum frequency, and phase shift is increased at frequencies below the pendulum frequency and decreased at frequencies above the pendulum frequency. These effects are seen to increase with load weight. Both gain and phase margins are reduced by the load. The loss in phase margin is associated with the increased phase shift at frequencies below the pendulum frequency, and the loss of gain margin is associated with gain increases in the region of the 180° phase shift (near 10 rad/sec). The longitudinal axis responses exhibit reduced load effects compared to the lateral axis. Helicopter stability and control derivatives change with the increased thrust required by the load, and these changes are thought to produce the gain increases which result in loss of gain margin with load.

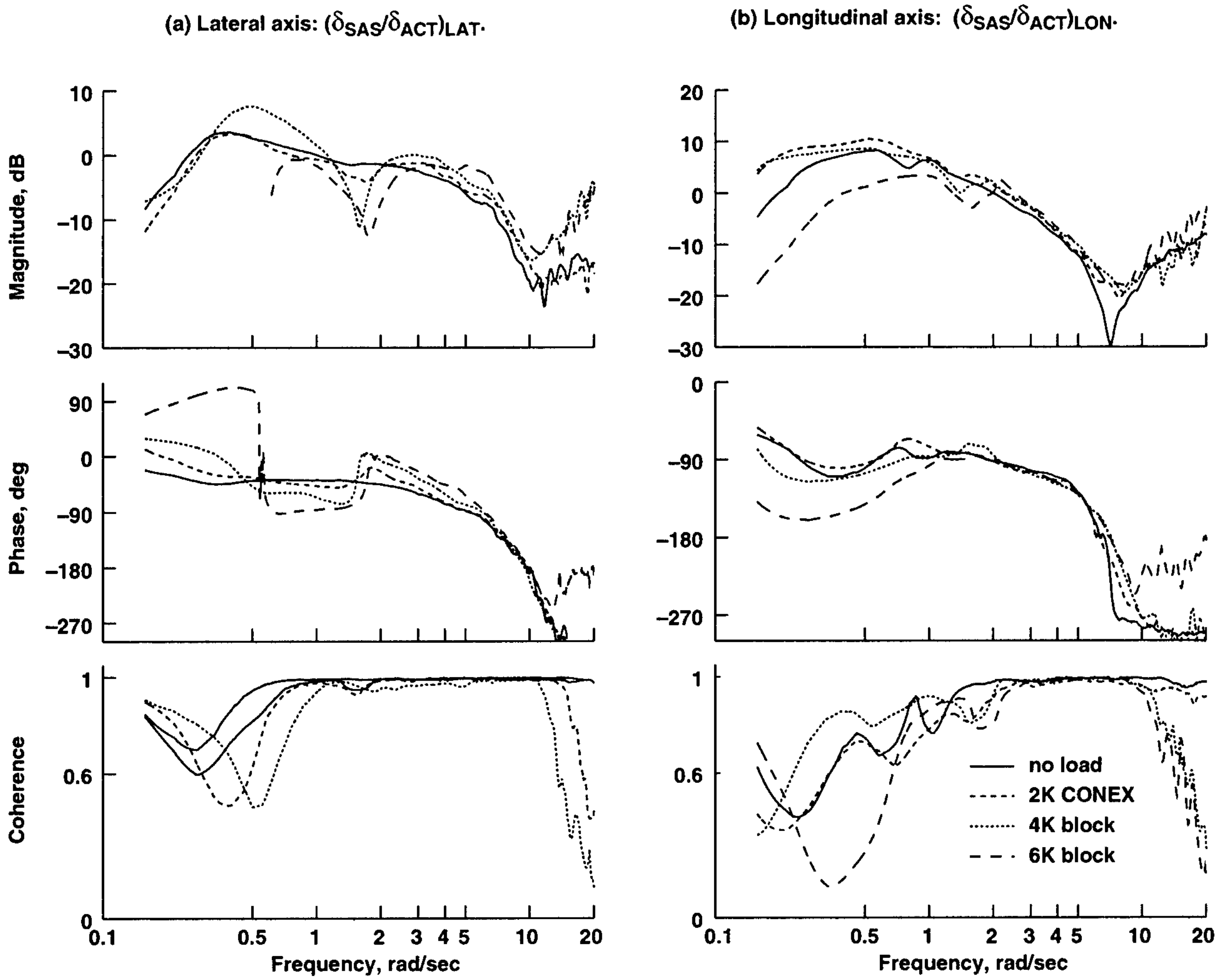


Figure 14. Effect of load on hover broken loop response.

Collected stability margin results are plotted versus airspeed in figure 15. The lateral axis margins show a consistent loss of phase margin because of the load and a loss of gain margin, mainly at hover. This is consistent with industry experience that the lateral axis is the one for which stability is normally degraded by the load (ref. 2), particularly at hover. The longitudinal axis margins show little variation of phase margin whereas gain margins degrade for the block loads, with large losses at the higher speeds.

Lateral axis stability margin results are shown in figure 16 in a plot of gain margin versus phase margin. Margin losses at hover are about 4 dB and 30° for the 4,000-lb block load. A flight-test data point for a 9,000-lb test load (ref. 2) is included to indicate the increased loss of margins with increasing load weight. The UH-60A is seen to have large margins from the specification minimums (45°, 6 dB) so that moderate losses in margin owing to the load do not threaten its stability. However, other aircraft exist with base margins close to the minimums and such losses would be more critical for them.

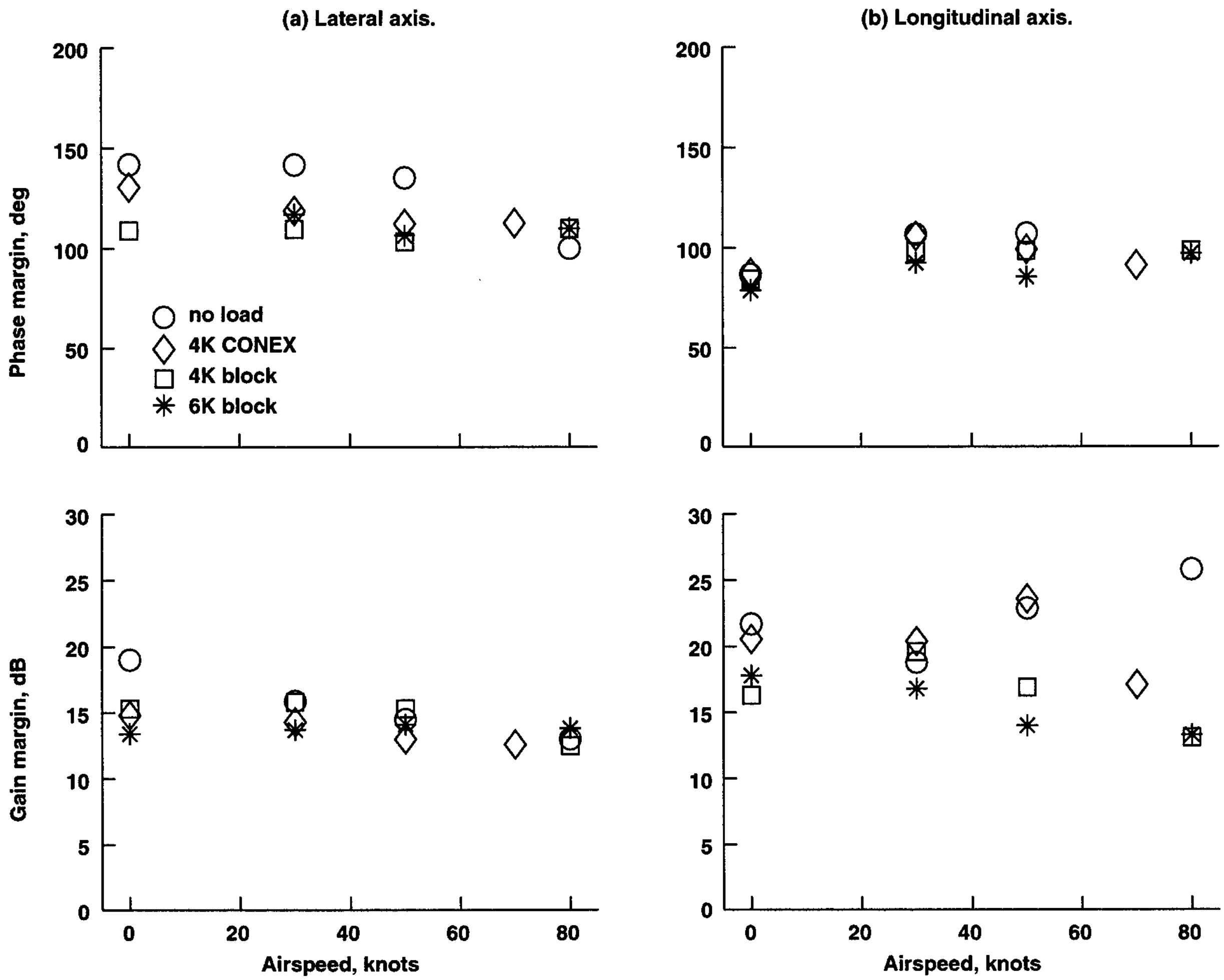


Figure 15. Stability margins versus airspeed.

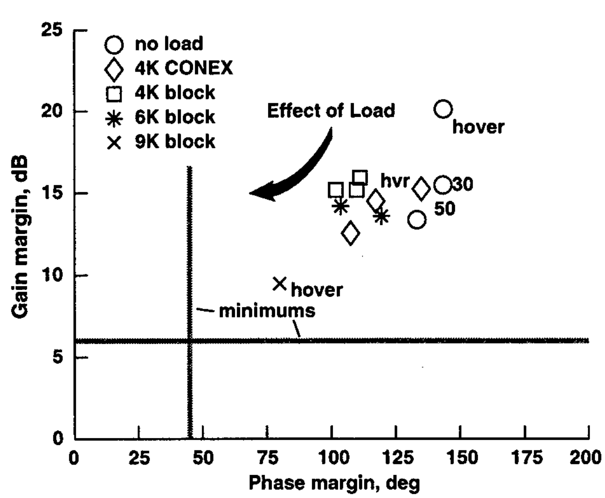


Figure 16. Lateral axis stability margins.

Load Pendulum Roots

The load roots were identified by fitting the transformed load angular rate responses, $p2'/\delta_{LAT}$, $q2'/\delta_{LON}$, with a second-order pole. A sample fit is shown in figure 17. The load responds chiefly around the pendulum frequency; gain rises to a maximum there and phase shifts through 180° across this frequency. The coherence drop seen near the pendulum frequency in figure 17 was present in all load response results. The precise cause of this coherence loss at a response peak has not yet been identified.

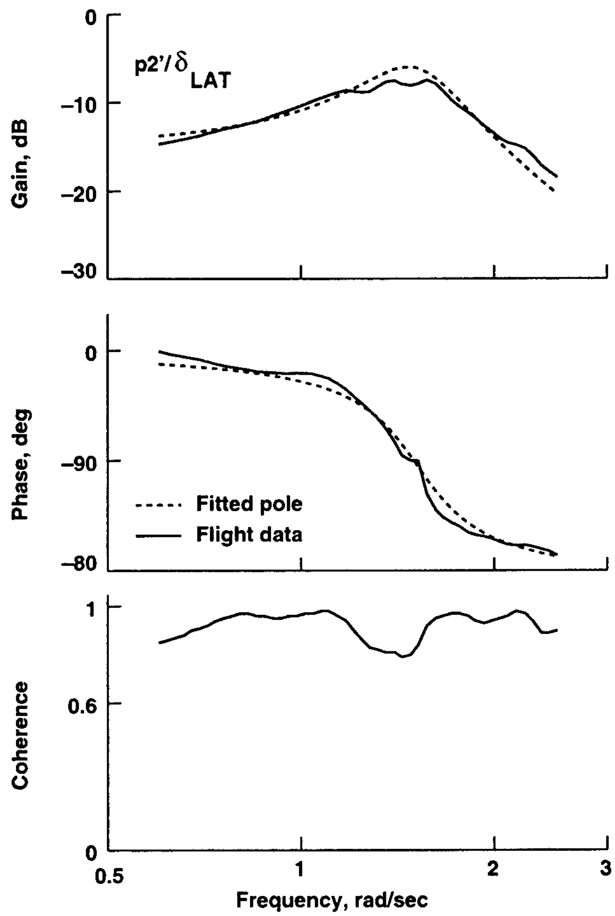


Figure 17. Identification of pendulum roots from load angular rate response: hover, lateral axis, 4,000-lb CONEX ($\zeta = 0.158$, $\omega = 1.5$ rad/sec).

Results for damping and natural frequency are plotted versus airspeed in figure 18 for the ballasted CONEX and 4,000-lb block loads. Natural frequency is about the same for both axes and loads (1.5 rad/sec), and is independent of airspeed. Longitudinal axis damping is consistently lighter (0.1 or less in most cases) than lateral axis damping (above 0.15). Linear analysis indicates that the helicopter Lp, Mq are the primary sources of damping for the pendulum modes, and that the reduced

longitudinal axis damping is a result of the differences in inertia and the related coupling of attitude dynamics with load pendulum motions. This difference in damping was also clearly visible in the doublet response time-histories. Damping varies only a little with airspeed in these results. Considerable load yaw motion developed with airspeed for the ballasted CONEX but without coupling to the pendulum modes; that is, the load aerodynamics mostly drove the yaw degree of freedom without modifying the pendulum motions.

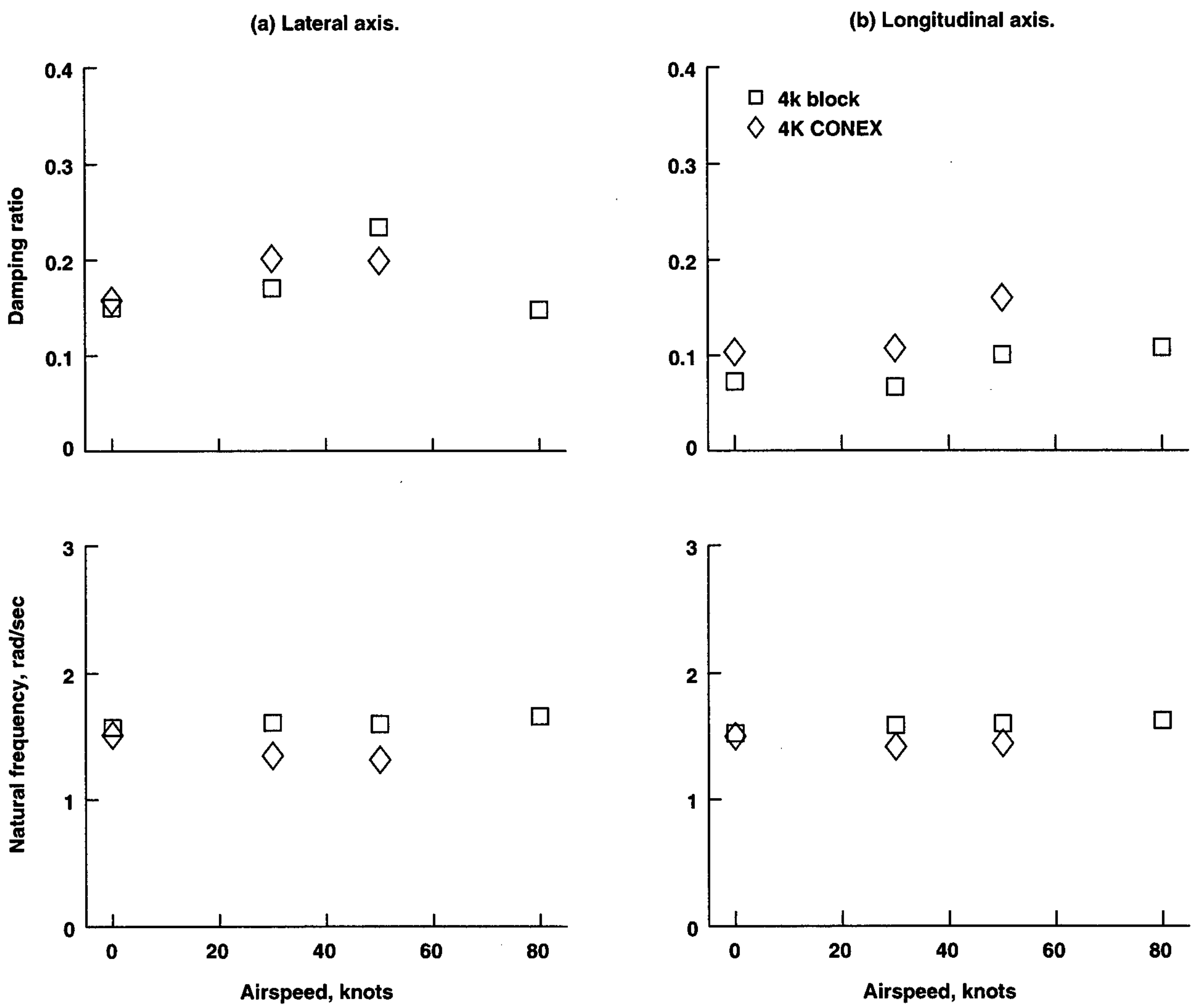


Figure 18. Load pendulum roots versus airspeed.

The load pendulum roots were also estimated by fitting the load angular rate time-history response to doublet inputs. Good agreement with the frequency-domain results was obtained. In the absence of load instrumentation, the pendulum roots can be estimated by fitting the helicopter broken loop response with a pole-zero combination in the region of the pendulum frequency. Results from this indirect computation agreed moderately well with results from the load signals.

SLUNG-LOAD SIMULATION

The general objective is to implement and validate a simulation capable of accurately predicting the key dynamic parameters of slung-load configurations discussed in the foregoing text.

At Ames, aircraft simulations are normally available with a standardized implementation of the Newton-Euler rigid-body equations of motion. Such simulations can be extended to slung-load configurations by appending the slung-load model using the logical flow shown in figure 19. The load aerodynamics and two-body equations of motion are appended as shown and used to compute the hook forces and c.g. moments applied to the helicopter, which are then added to the aircraft force and moment sums to drive its single rigid-body dynamics. The two-body dynamics module necessarily carries a duplicate copy of the aircraft Newton-Euler equations. The two sets of aircraft states are coordinated by resetting the helicopter position and velocity states in the two-body equations to those in the aircraft equations at the start of each integration step.

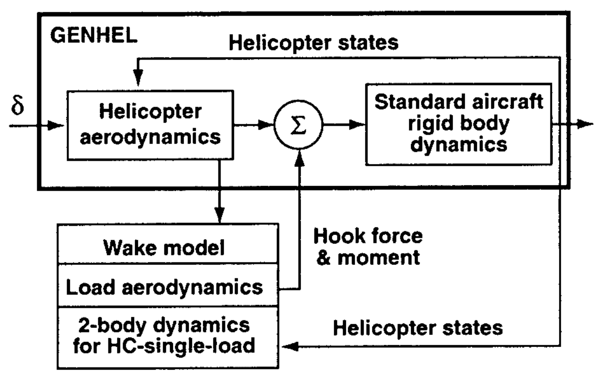


Figure 19. Integration of load model into standard helicopter simulation.

This arrangement was used in the present study, beginning with an existing UH-60A simulation based on Sikorsky's GenHel model. That model (ref. 10) has been independently extended and validated at Ames for handling-qualities studies (refs. 11, 12), and at Sikorsky (ref. 2). It contains a blade-element rotor model (five elements for each rigid blade, dynamic inflow), a rigid-body fuselage with aerodynamics based on wind-tunnel data, and component models of the engine, drive train, and control system. All the control system variables measured on the aircraft also occur in the simulation. The two-body slung-load equations of motion for general multi-cable slings and loads were implemented as given in reference 14. The sling legs can be elastic (12 rigid-body degrees of freedom (DOFs)) or inelastic (9 DOFs). The hook-sling attachment is modeled as one that can transmit forces but not moments. This is a standard attachment model consistent with a swiveled sling, but does not capture the sling windup of the unswiveled CONEX which affects the load yaw dynamics.

Load static aerodynamics and rotor downwash effects are included. Wind-tunnel data for the CONEX static aerodynamics were provided by the Technion Institute (ref. 15). The final set of

tunnel data (fig. 20) was taken with model supports designed to minimize measurement errors. Measurement errors were revealed by studies of a cube model which has extensive known aerodynamic symmetry properties (ref. 15). The data cover angles of attack from –90° to 90° and sideslip angles from 0° to 90° in 5° intervals and comprise a uniquely comprehensive and accurate set of load wind-tunnel data. These are extended in the simulation to the complete range of load attitudes ($\alpha \in [-180, 180]$ and $\beta \in [-90, 90]$) using symmetry rules about zero sideslip angle, and about $\alpha = 90°$ and $-90°$. The CONEX skids were included in the wind-tunnel model and these remove the symmetry of a strictly rectangular box about $\alpha = 0$ (e.g., lift and pitching moment are nonzero at $\alpha = 0$), and symmetry about $\beta = 90°$ is modified to radial symmetry about the point $(\alpha, \beta) = (0, 90)$. These symmetries were confirmed by data taken well outside the region mapped in figure 20. The principal components are the drag, which determines the load trail angle and which varies moderately with orientation, and the yaw moment, which drives the CONEX to large yaw rates as airspeed increases and which is statically stable in yaw in limited ranges near 0° and 90° sideslip.

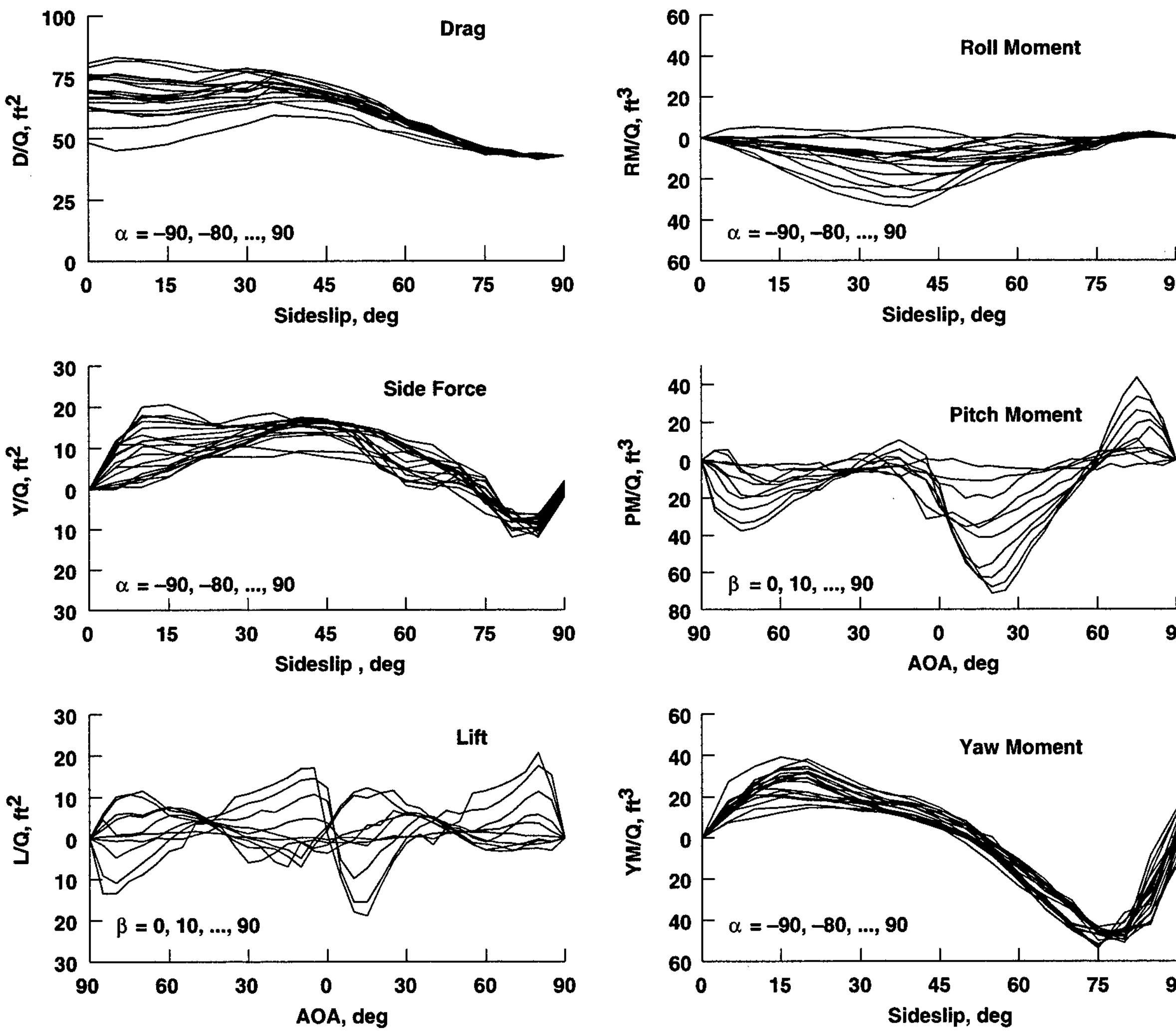


Figure 20. CONEX static aerodynamics wind-tunnel data (wind axes components divided by dynamic pressure).

Main rotor downwash can result in significant airflow over the load in hover, of the order 50 knots. The rotor wake narrows to half the rotor diameter in the far wake (starting at about 1.5 rotor radii) and the axial wake velocity correspondingly increases to twice the inflow. Air velocity at the load was computed as a function of load c.g. location in the wake, using measured data from references 37 and 38. In addition, the (swiveled) CONEX was observed to spin at 30-40 deg/sec in hover because of the rotational component of the downwash. This simulation is described in greater detail in references 20 and 21.

SIMULATION VALIDATION

Validation is based on a comparison of the simulation and flight data frequency responses required to compute the key dynamic parameters of interest, and on a comparison of the parameter values obtained. The present work considers the lateral and longitudinal on-axis responses over the frequency range of interest in handling-qualities work, that is, 0.05 to 2 Hz. The simulation aircraft was maintained centered about the reference flight condition by adding a three-channel low gain rate and attitude feedback loop, following reference 39. The effects of correlated off-axis inputs from the stabilizing control were removed in the CIFER® analysis. In the following discussion, the fidelity of the GenHel helicopter model is reviewed before determining the fidelity of the GenHel-slung load model.

No-Load Simulation Fidelity

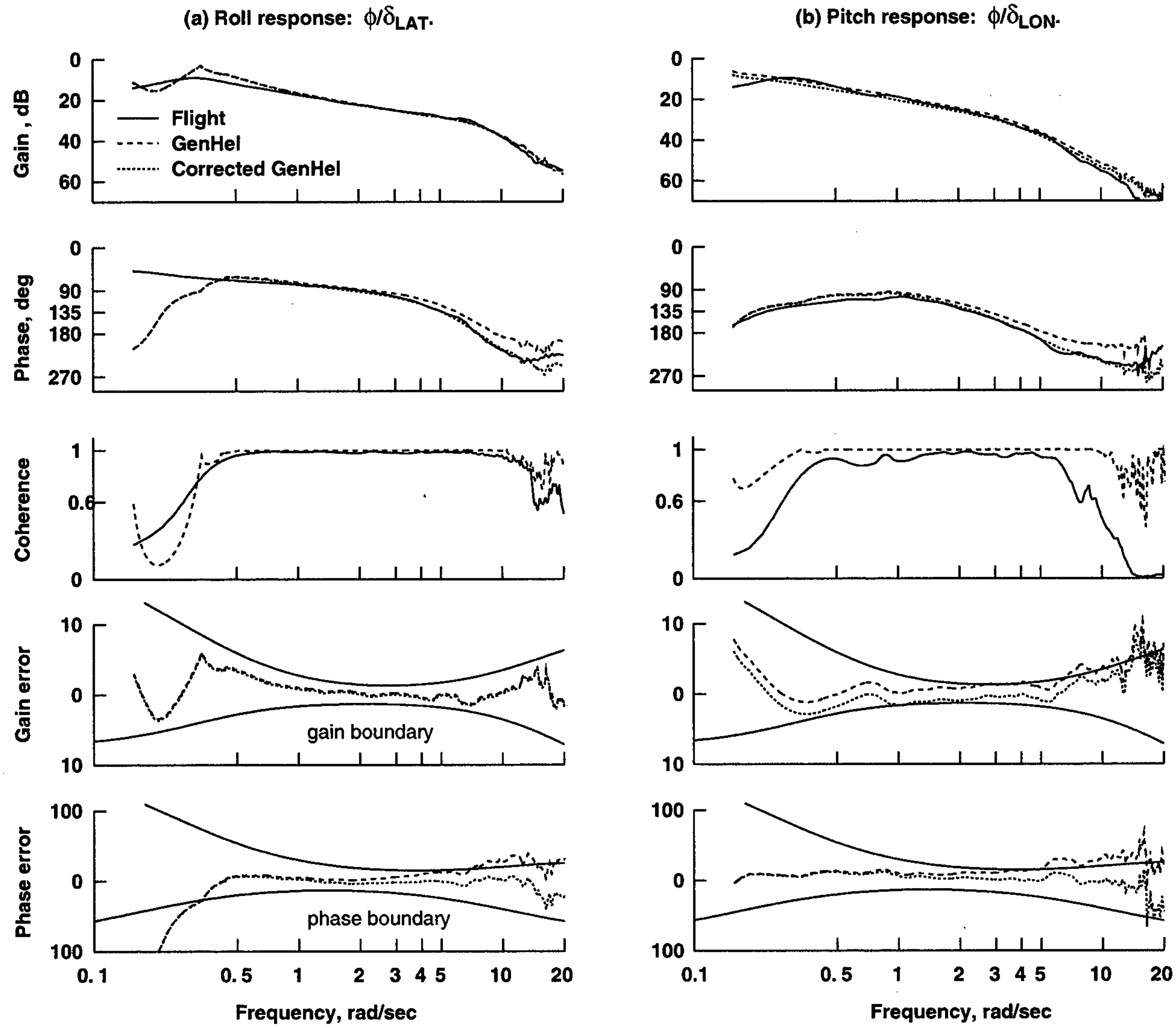
Handling qualities–The closed-loop attitude responses at hover are compared with flight results in figure 21. An error function is formed by dividing the simulation response by the flight response. Identical responses would produce unity (0 dB gain and 0° phase). The error functions are shown in the figure along with a frequency-dependent error boundary representing the threshhold at which a pilot can detect differences between simulation and aircraft dynamics (refs. 40, 41). Transfer functions for the upper and lower gain and phase fidelity boundaries are given in reference 40 as:

$$G_U(s)=\frac{3.16s^2+31.61s+22.79}{s^2+27.14s+1.84}$$

$$G_L(s)=\frac{.0955s^2+9.92s+2.15}{s^2+11.6s+4.96}$$

$$\Phi_U(s)=\frac{68.89s^2+1100.12s-275.22}{s^2+39.94s+9.99}e^{.0059s}$$

$$\Phi_L(s)=\frac{475.32s^2+184100s+29456.1}{s^2+11.66s+.0389}e^{-.0072s}$$



Correction function = $Ke^{-\tau s}$

Axis	K	τ (sec)
Lateral	1.00	0.0485
Longitudinal	0.81	0.051

Figure 21. Helicopter attitude-response validation: no load, hover.

These boundaries were established in reference 41 for the longitudinal axis and can reasonably be applied to the lateral axis as well for the present discussion. Other proposed frequency-domain mismatch criteria for high-fidelity simulators are discussed in references 42 and 43. The results in figure 21 show that the lateral axis error function magnitude is within the boundaries, but phase is outside the boundary above 8 rad/sec, and the longitudinal axis error gain and phase are both outside the boundary at higher frequencies. Thus, the present GenHel simulation is inaccurate in the region where phase shift reaches 180° and on which gain bandwidth and phase delay depend.

The error function can be fitted with a low-order transfer function to obtain an empirical correction to the simulation frequency responses. In this case, a simple gain and time delay sufficed, and parameter values, given in figure 21, were found to be insensitive to airspeed. The corrected responses in figure 21 show good agreement with flight data and residual errors are well within the fidelity boundaries. A comparison of the handling-qualities parameter values from the corrected simulation responses and flight data (not shown) showed good agreement at all airspeeds. The correction function will be applied to all closed-loop simulation responses in the remainder of this report.

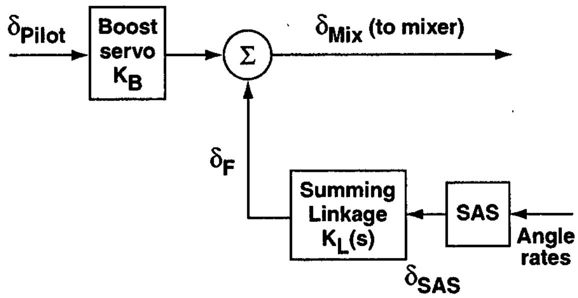
The error function results are consistent with a previous validation exercise in which an end-to-end 50-msec delay in the flight data relative to the simulation was found (ref. 11). Further comparisons with flight measurements at several points in the control system were made, and they indicated that about half the unmodeled delay is in the rotor model and half in the control system. The servo dynamic models have been verified, so that the control portion of the delay is likely a result of unmodeled linkage and mixer dynamics. It was initially thought that the rotor portion of the delay was caused by the lack of in-plane (lead-lag) blade bending based on a CH-53 study in reference 44. However, analysis has shown that this is not the case for the UH-60 and has pointed to the rotor integration scheme as a source of lead in the simulation model.

Stability margins–The SAS servo output sums with the pilot input as modeled in figure 22 to generate the mixer input. Flight data are available from sensors measuring the pilot stick deflection, δ_{PILOT}, the mixer input, δ_{MIX}, and the SAS servo output, δ_{SAS}, but not the linkage output, δ_F. Stability margins are defined from the "broken loop" control response, $\delta_F(s)/\delta_{MIX}(s)$, but are often evaluated from the SAS servo and mixer sensor signals (FR_1 in fig. 22). However, δ_F can be constructed indirectly as the difference between the mixer input and pilot signals and the stability margins can be computed from the indirect response (FR_2 in fig. 22). The simulation represents the summing linkage as a simple gain determined from low frequency data, and the simulation gives identical responses by either method. The flight data do not show identical responses, as seen in figure 23; this reveals the presence of linkage dynamics. Differences are large at higher frequencies, which implies a significant difference in gain margins, depending on the signals used for their computation. The indirect computation, FR_2, has been used for all flight results herein since it measures the actual feedback to the rotor. The direct computation, FR_1, would yield conservative (reduced) gain margin results owing to the higher gain in the region of 180° phase shift. Similarly, simulation results for gain margin will usually be conservative owing to the unmodeled linkage dynamics. However, phase margin prediction is unaffected since it depends on response behavior at lower frequencies. A comparison of simulation and flight data results in reference 20 shows excellent phase margin agreement and conservative simulation gain margin results at all airspeeds.

Slung-Load Simulation Fidelity

Handling qualities–Closed-loop attitude responses for the 4,000-lb block at hover are compared in figure 24. Lateral axis gain and phase differences at higher frequencies (6-11 rad/sec) suggest some excitation of the rotor dynamics not captured by the simulation. A similar difference occurs at all airspeeds. The corresponding error function (not shown) is close to the limit of the accuracy boundary in this range. Differences near the pendulum frequency are more noticeable, but occur where scatter owing to reduced coherence can occur. Despite these frequency response differences,

parameter values for the 4,000-lb block in figure 25 exhibit good agreement between flight and simulation at all flight conditions. The different number of lateral axis bandwidth values for the two cases at hover and at 80 knots is a result of small unimportant differences in their frequency responses.



$$FR_1 = \frac{K_L \delta_{SAS}(s)}{\delta_{MIX}(s)}$$

$$FR_2 = \frac{\delta_{MIX}(s) - K_B \delta_{Pilot}(s)}{\delta_{MIX}(s)} = 1 - \left(\frac{\delta_{MIX}(s)}{K_B \delta_{Pilot}(s)}\right)^{-1}$$

Figure 22. Computation of stability margins.

Stability margins–Parameter values for the 4,000-lb block (fig. 26) show good agreement with flight results at all flight-test conditions. Simulation gain margins are consistently below the flight values, a result of unmodeled control linkage losses as previously noted.

Pendulum modes–The on-axis load angular rate frequency responses at hover are compared in figure 27 for the 4,000-lb block load. The simulation is seen to reproduce the flight response closely. A dip in coherence occurs in the region of the pendulum frequency where the response gain reaches its peak, especially in the longitudinal axis response. The coherence dip is captured by the simulation but its physical cause has not been established.

A comparison of time-history doublet responses in figure 28 shows good agreement in apparent frequency and damping of the pendulum mode excited by the input. The simulation does not reproduce the small amplitude mode at about 4 Hz seen in the flight data. A detailed examination of time-history data shows that the smaller off-axis signals agree in magnitude and frequency content out to 2 Hz, although flight-simulation differences can be as large as the signals.

Results for the CONEX pendulum roots are collected in figure 29. The simulation results are given with and without load static aerodynamics. Pendulum frequencies from flight and simulation data agree closely at all airspeeds and on both axes. The simulation predicts that frequency is nearly fixed with airspeed and that it is unaffected by load aerodynamics; these trends are matched by the flight data. Hover damping is well matched by both simulation cases and is therefore unaffected by the

rotor downwash. The simulation predicts that damping is nearly fixed with airspeed in the absence of load aerodynamics, and rises with airspeed when load aerodynamics are included, particularly the lateral axis damping. The flight data show a tendency toward increased damping with airspeed.

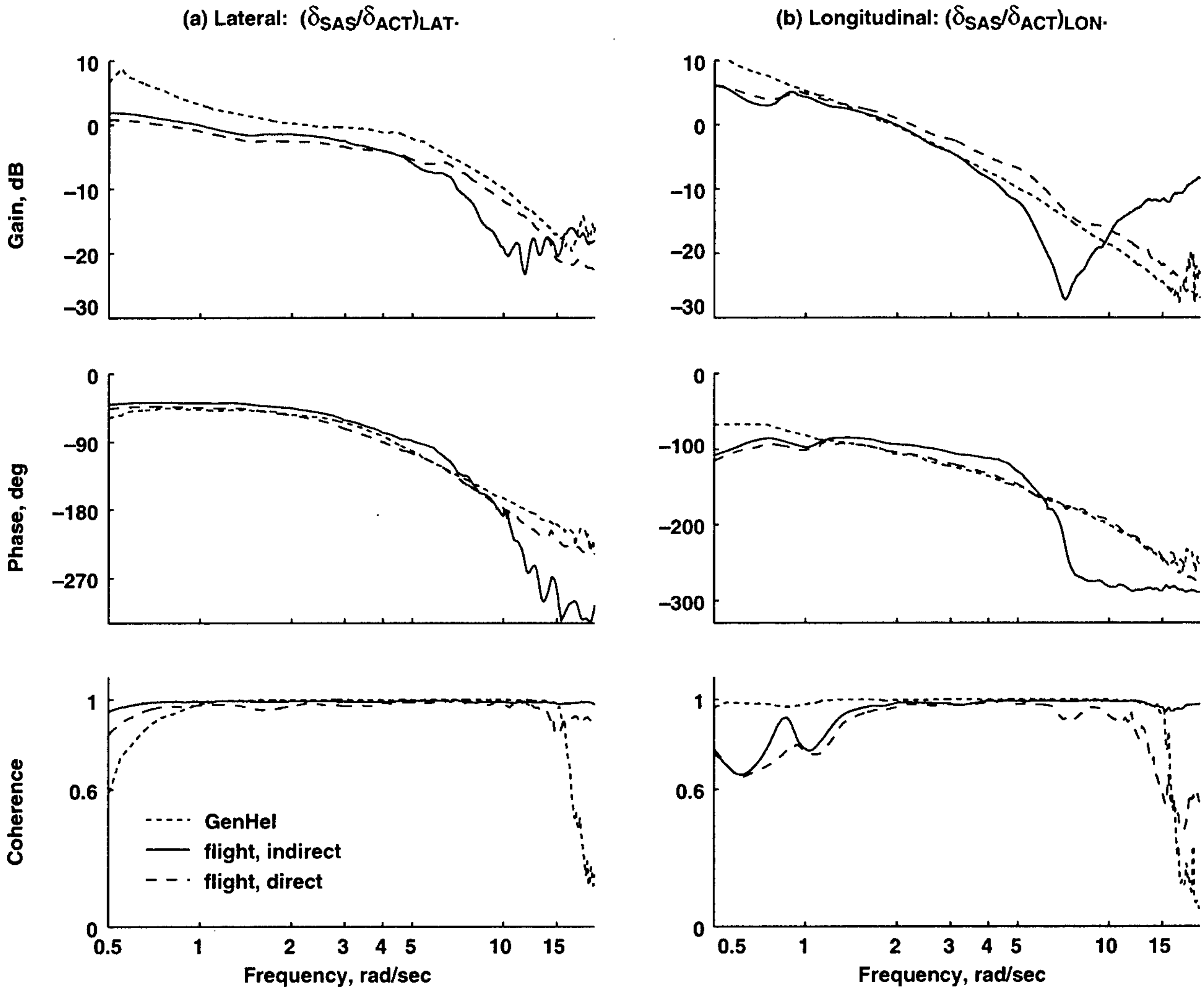


Figure 23. Broken loop response validation: no load, hover.

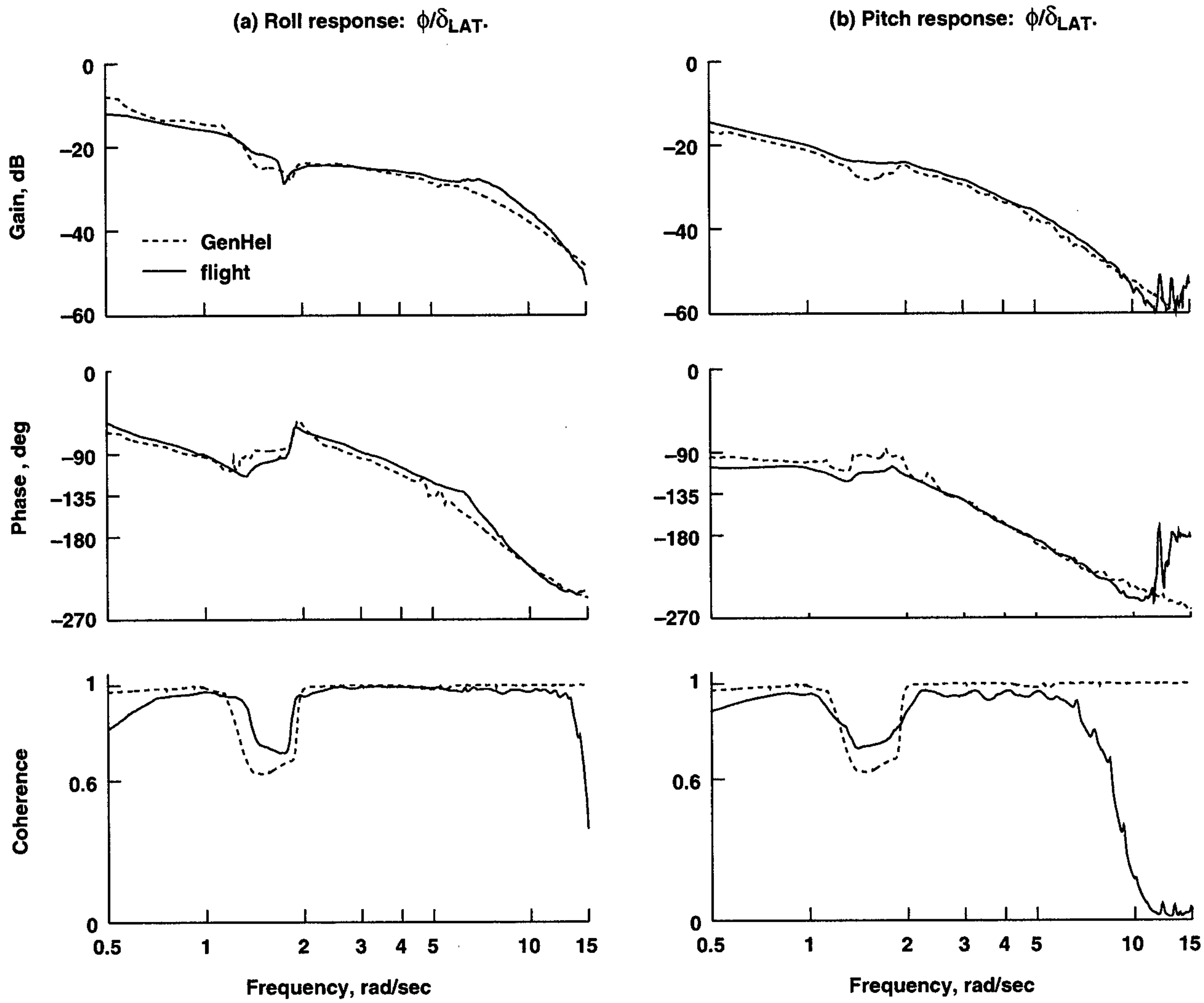


Figure 24. Helicopter attitude-response validation: 4,000-lb block load, hover.

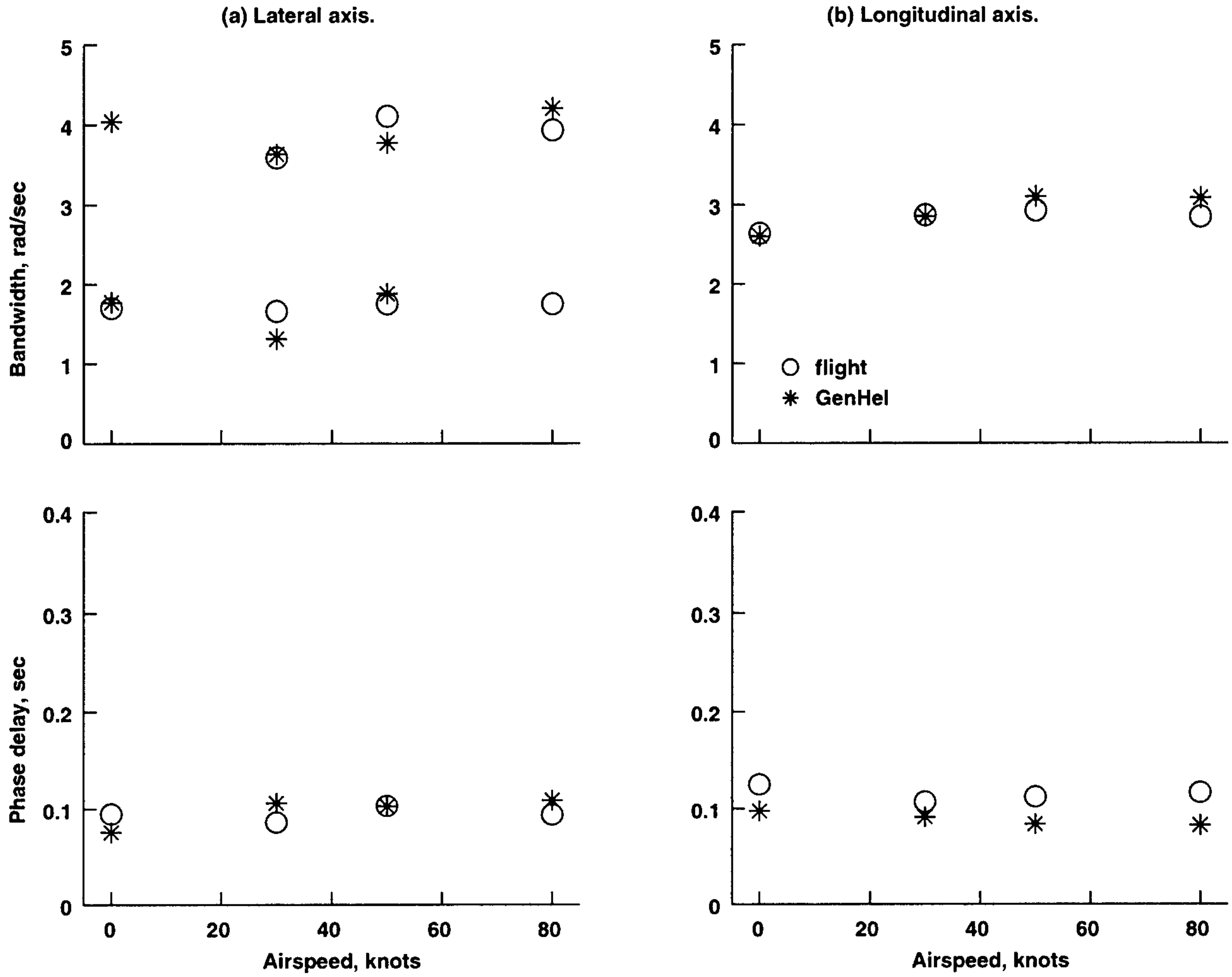


Figure 25. Handling-qualities parameters: 4,000-lb block load.

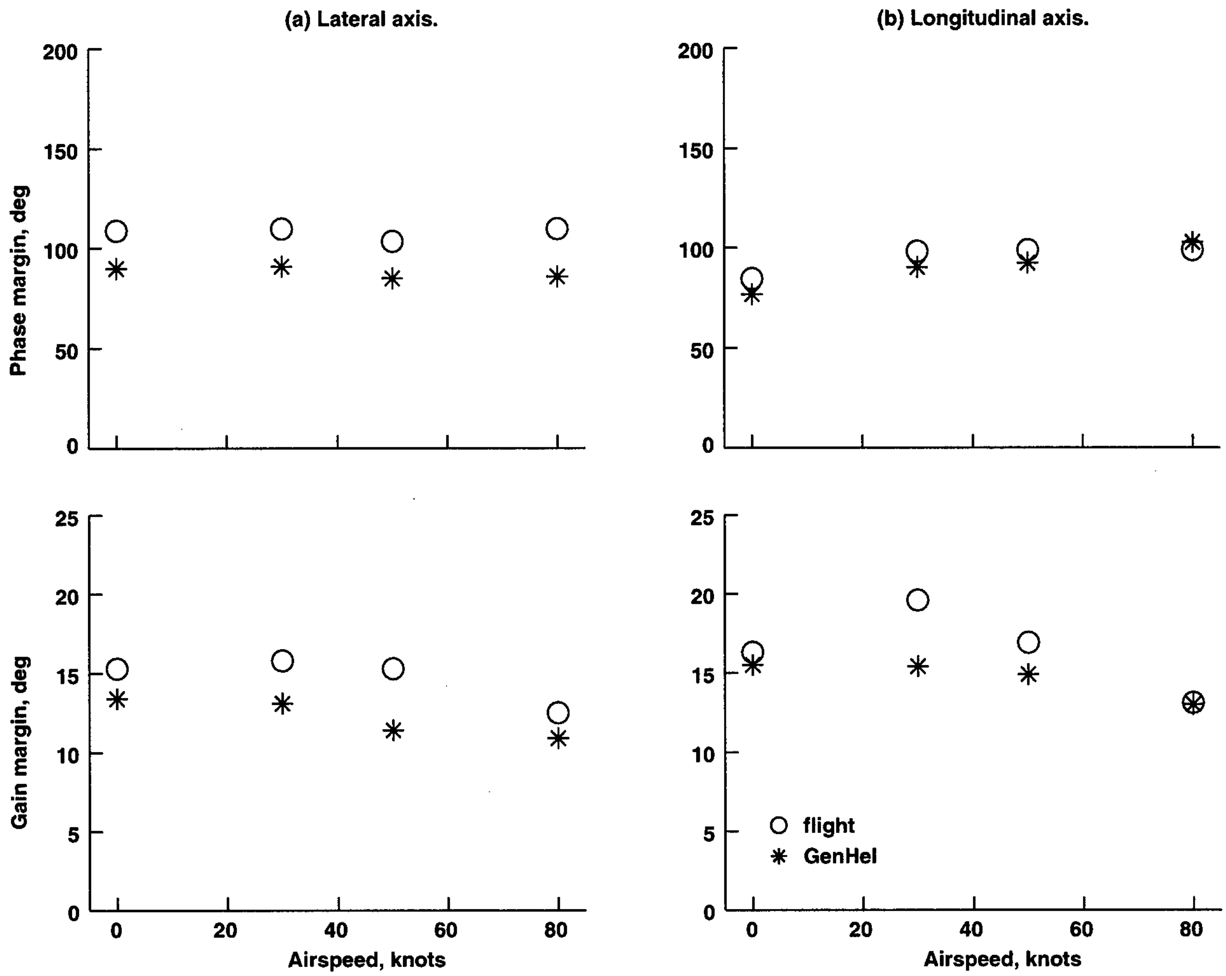


Figure 26. Stability margins: 4,000-lb block load.

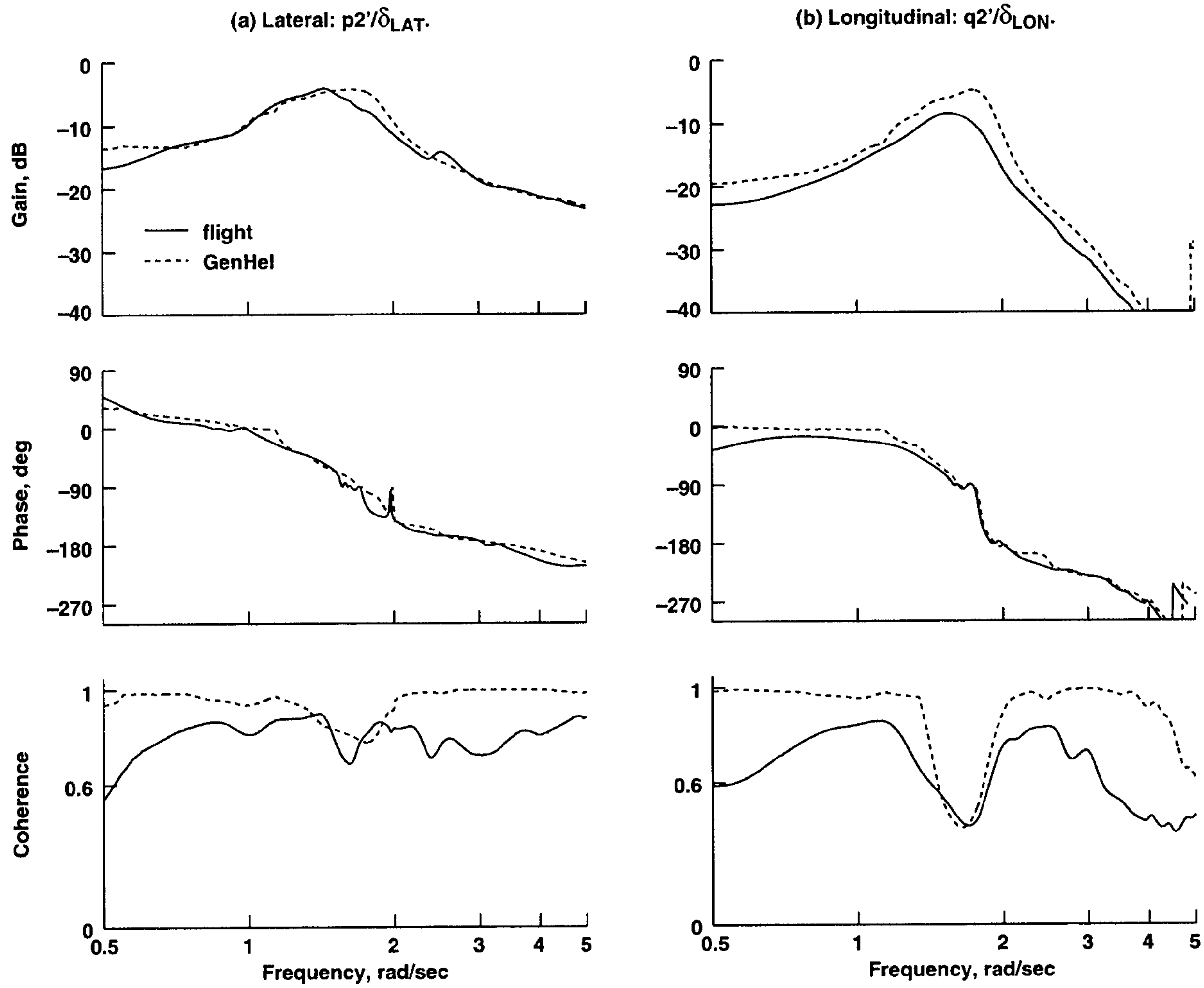


Figure 27. Load angular rate response validation: 4,000-lb block load, hover.

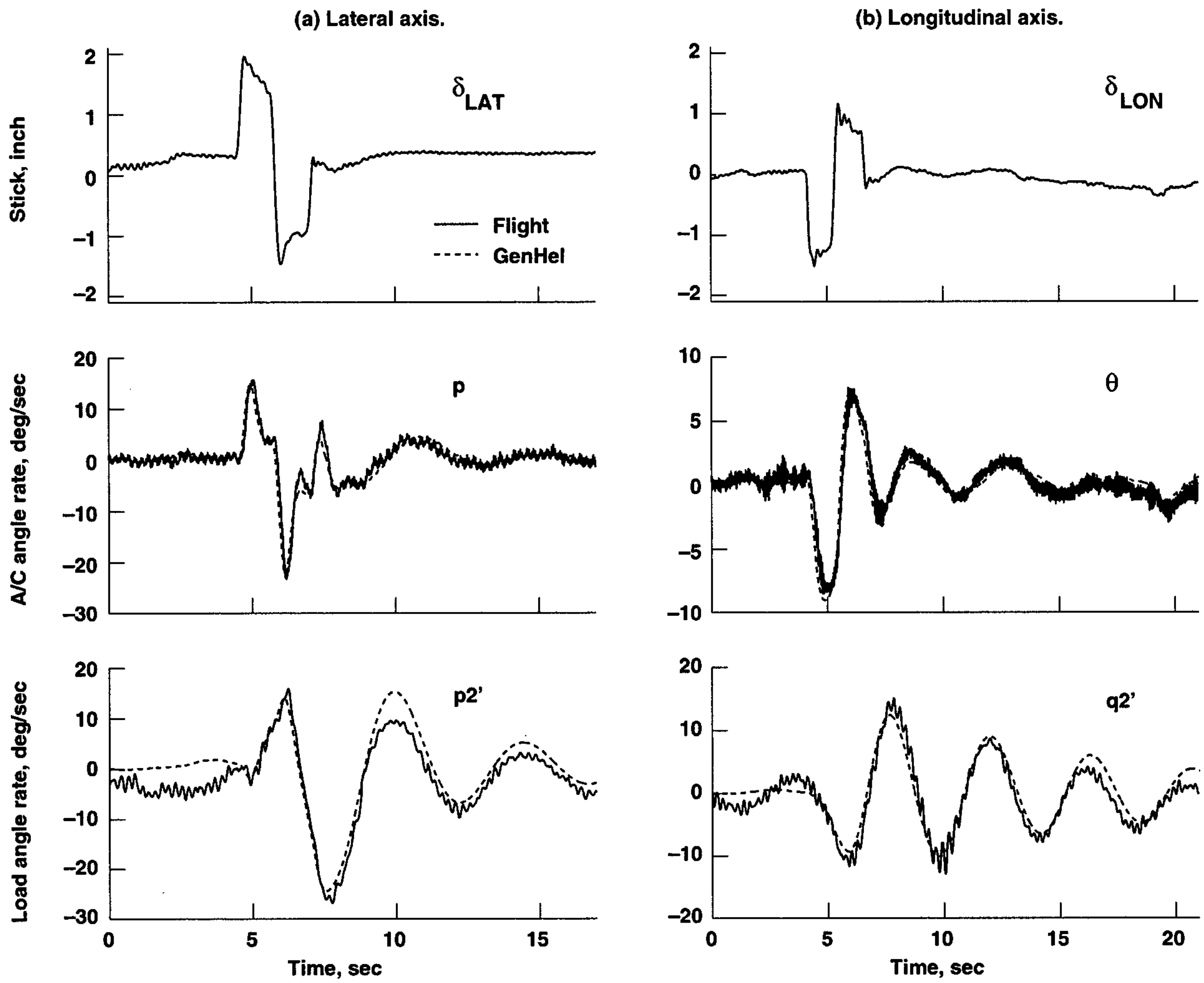


Figure 28. Doublet response comparison: 4,000-lb CONEX, hover.

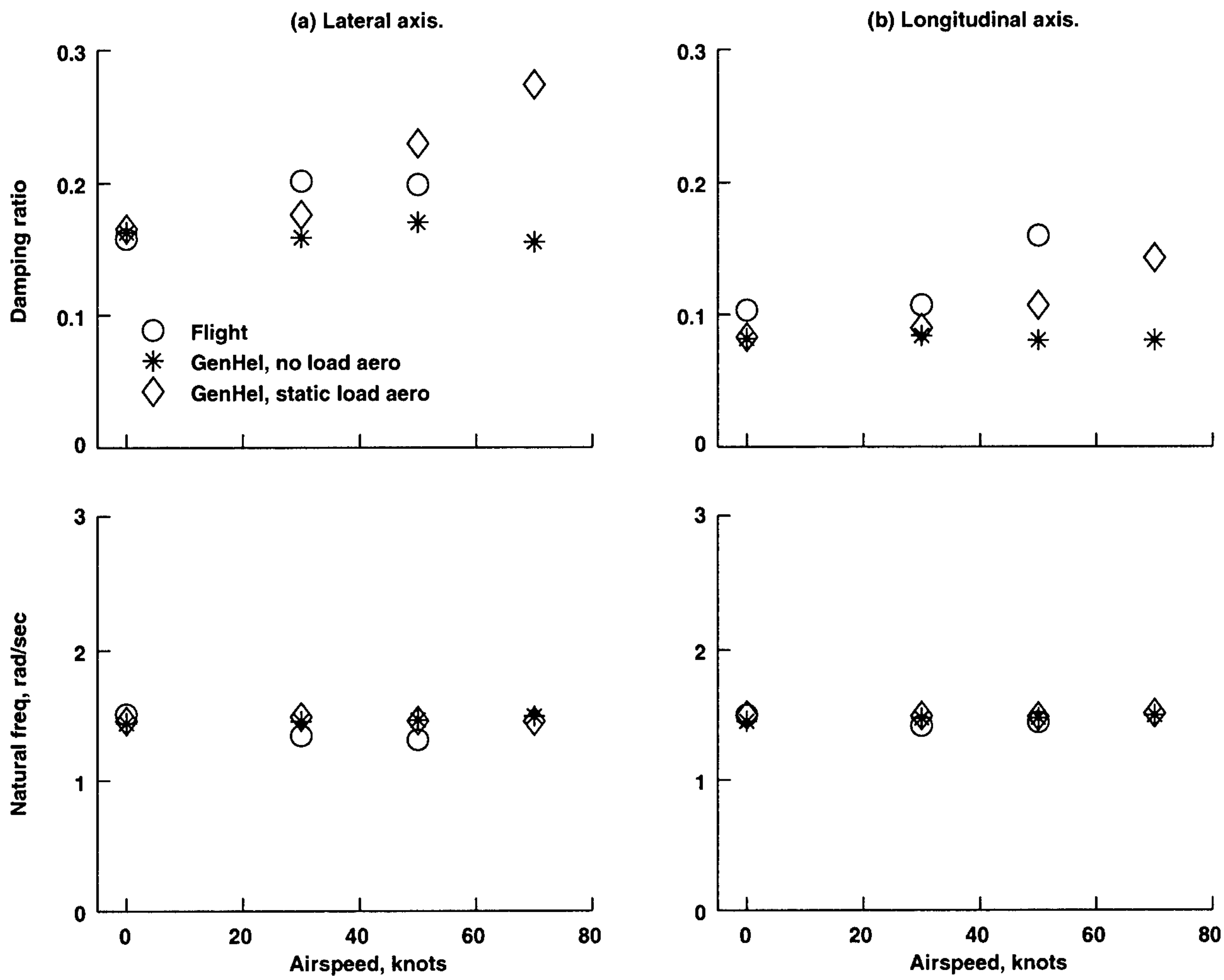


Figure 29. Pendulum roots: 4,000-lb CONEX load.

CONCLUSIONS

The main objectives of the study were to (1) demonstrate an efficient method for flight-test evaluation of slung-load configurations and (2) develop a validated simulation capable of realistic prediction of the key dynamic characteristics of slung-load systems. The test configurations were a UH-60A Black Hawk helicopter and various loads, including an instrumented CONEX cargo container. These objectives were achieved. Some detailed results follow.

1. A system for computing aircraft stability and handling qualities, and load-stability parameters during flight testing using telemetered frequency-sweep data has been demonstrated. The required computations with CIFER® required 40 sec on a 200-MHz workstation. Accuracy as good as postflight analysis was obtained, limited only by the quality of the telemetered data.

2. A portable load instrumentation package was designed and used on two of the test loads. This instrumentation, composed of ordinary aircraft accelerometers, rate gyros, and a digital compass, sufficed for the identification objectives of the study. Improved sensors would be required to encompass the full dynamic range of aerodynamically active loads in forward flight, and additional sensors would be required to measure load aerodynamics from the flight data.

3. Numerical results for the test UH-60A aircraft sling-load configurations indicated strong load effects on the aircraft lateral and longitudinal axes frequency responses in the region of the load pendulum frequency and moderate effects at higher frequencies from 1 to 2 Hz owing to load-vehicle dynamic interactions and to the increased thrust levels required by the load. These effects increased with load weight. Stability margins and lateral axis bandwidth were reduced for most test conditions. The load pendulum modes were lightly damped with greater damping and greater coupling with aircraft attitude on the lateral axis than on the longitudinal axis. Similar results are expected to occur for single-point suspension configurations generally.

4. A slung-load simulation was implemented, validated, and shown to match flight-test frequency responses and key dynamic parameters in the evaluation of slung-load handling qualities, stability margins, and load pendulum stability. The validation focused on the longitudinal and lateral axes responses out to 2 Hz, and revealed residual unmodeled dynamic effects in the helicopter model in the range of 1-2 Hz. Empirical response corrections were determined and excellent agreement with the flight results was obtained for handling qualities parameters, and phase margin; gain margin results were conservative. Close agreement with flight results for the load responses and pendulum roots was obtained, including the effect of the load static aerodynamics.

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APPENDIX

COMPENDIUM OF UH-60A SLUNG-LOAD TEST FLIGHTS

This appendix provides a compendium of slung-load flight test data archived at Ames Research Center in the TRENDS data base utility (ref. 45) under tail number *BSL*. This includes base-line flights with no load and with the various load-sling configurations shown in figure 3 of the text. This appendix contains a summary of flights by load (table 1), a master list of available signals (table 2), and a catalog of records for each flight (table 3). All records have been stored at 100-Hz data rate. The flight records consist principally of lateral and longitudinal control frequency sweeps, steps, and doublets. A limited amount of data is included for directional and collective control inputs. The BSL data base contains additional flight records for the test UH-60A aircraft beyond those listed in this compendium, including the flight data of the handling qualities study of reference 24.

Summary of Flights by Load

Flights are summarized by load in table 1. The table indicates the airspeeds, control axes, control inputs, and signal groups available for each flight, as well as the record numbers archived in TRENDS. Load sensor signals are available for nearly all flights with the CONEX and for flights with the 4,000-lb block starting with flight 177.

Signals

A master list of signals is given in table 2. These are divided into three groups. Group TC ("test conditions") contains helicopter sensor signals plus some scaled control system signals. This group subdivides broadly into control system sensors, aircraft rigid-body state sensors, and air data sensors. Group LD contains the load instrumentation package signals, which are rigid-body state sensors. Group DP ("derived parameters") contains derived parameters which subdivide into (1) control system signals scaled to inches, (2) smoothed or derived variables for the helicopter rigid body states, (3) derived signals from the air data sensors, and (4) smoothed and derived signals from the load instrumentation.

A diagram of the helicopter control system and the control sensor locations is given in figure 30 along with the gains and scale factors used to scale the sensor outputs to inches. A backward/forward smoothing filter from reference 46 was used to remove vibration frequencies from the accelerometer, rate gyro, and some air data signals, and to obtain altitude rates and derivatives of the angular rate signals. The filter cutoff frequency for the filtered signals was 0.25 Hz for the altitude rate computations and 2.5 Hz for all other smoothed signals. Smoothed signals and derivatives were similarly generated for the load accelerometer and rate gyro outputs. The helicopter angular accelerometer signals are dominated by vibration and generally saturated. However, derivatives of the angular rate signals are provided in the derived parameters. The low airspeed sensor (LASSIE) y, z signal calibrations are doubtful. The load inclinometer signals are

proportional to the load accelerometer signals and measure angles relative to the apparent gravity rather than true gravity. The nonstandard sign convention for the load pitch rate gyro signal should be noted.

For some early flights data storage is incomplete; derived parameters were not generated for some flights or for records other than sweeps in some flights, and the basic signal group TC was incompletely archived in some cases. Signals in TRENDS can be addressed using the designations given in either the "item code" or "alias" columns of table 2.

Catalog of Records

Table 3 contains a detailed catalog of the records available in TRENDS for each flight.

The helicopter heading signal, item code DA02, was obtained from an unslaved directional gyro for flights prior to flight 177 and contained a random startup bias and drift. This bias was required to compute the CONEX load pendulum roots. Calibration records were taken, and the resulting starting bias and average drift rate are noted in the records catalog for flights 167 to 173. Heading is corrected by subtracting the bias value from DA02.

The record catalog notes the aircraft reference gross weight and c.g. station corresponding to aircraft, crew, and full fuel tanks (2,446 lb). The weight and c.g. station for any record can be adjusted for fuel use after noting that the fuel tank c.g. station is at 420.8 inches. This correction was included in the derived parameter computations.

TABLE 1. TRENDS DATA BASE: SUMMARY OF FLIGHTS BY LOAD

Load	Flight	Record numbers	IAS kts	Control axes	Control inputs	Signal groups	Notes
none	153	1-18	80	all axes	sweeps, dblts	TC, DP	
	154	1-14	80	lat, lon	sweeps, dblts	TC	
	157	1-49	0 - 130	NA	trims only	TC	air data cals
	170	1-71	0	lat, lon	sweeps,dblts	TC, DP	
			0	coll	doublets		
			30	lat, lon	sweeps, dblts		
			50	lat, lon	sweeps,dblts		
			50	coll	dblts		
1K plate	151	2-17	0	all axes	sweeps, dblts	TC	
	160	1-42	80	lat, lon	sweeps, dblts	TC	reduced signals

TABLE 1. TRENDS DATA BASE: SUMMARY OF FLIGHTS BY LOAD (CONTINUED)

Load	Flight	Record numbers	IAS kts	Control axes	Control inputs	Signal groups	Notes
4K block	156	15-59	20 - 120	lat, lon, pedal	steps, dblts	TC	
	158	1-93	0,60,80,100	all axes	steps, dblts	TC	
	159	1-57	0	all axes	sweeps, dblts	TC, DP	
	161	1-55	80	all axes	sweeps, dblts	TC	reduced signals
	177	2-17	0 0 30	lat, lon coll lon	sweeps, dblts 1 dblt sweeps	TC, LD, DP	uncalibrated SAS signals
	178	1-31	0 30 30 50	lon lat, lon coll lat, lon	sweeps sweeps, dblts dblts sweeps, dblts	TC, LD, DP	no mixers, SAS, boom, radalt signals
	180	4-20	0 50	lon lat, lon	sweeps, dblts sweeps, dblts	TC, LD, DP	uncalibrated SAS signals
	182	1-31	0 30 80	lat lat, lon lat, lon	sweeps, dblts sweeps, dblts sweeps, dblts	TC, LD, DP	
2KCONEX	162	12-21	0 to 60	NA	Trims, turns	TC	envelope clearance
	164	1-4	40	lat	1 sweep	TC, LD, DP	
	167	1-32	0 0	lat, lon coll	sweeps, dblts dblts	TC, LD, DP	
4KCONEX w swivel	169	1-18	0 30	lat lon	sweeps sweeps	TC, LD, DP	
	179	4-22	0 0 30 30	lat,lon coll lat, lon coll	sweeps, dblts dblts sweeps, dblts dblts	TC, LD, DP	
4KCONEX	168	1-35	0 0	lat, lon coll	sweeps, dblts dblts	TC, LD, DP	
	172	1-52	0 30 50	lat lat, lon lat, lon	sweeps sweeps, dblts sweeps, dblts	TC, LD, DP	
	173	1-50	0 60 70	lon lat, lon lat, lon	sweeps sweeps, dblts sweeps, dblts	TC, LD, DP	
6K Block	181	1-30	0 30 50	lat,lon lat,lon lat, lon	sweeps, dblts sweeps, dblts sweeps, dblts	TC, LD, DP	
	183	1-25	50 80	lat, lon lat,lon	sweeps, dblts sweeps, dblts	TC, LD, DP	

TABLE 2. TRENDS SIGNALS AND VARIABLES

(a) Group TC: Helicopter Sensors

Item code	Alias	Description	Positive direction	Units	Range Min	Max
D100	LONSTK	longitudinal cylic stick position	aft	%	0	100
D101	LATSTK	lateral cyclic stick position	right	%	0	100
D102	PEDAL	directional control position	right pedal	%	0	100
D103	COLLSTK	collective stick position	up	%	0	100
D003	STBLR	stabilator angle	TE down	deg	-10	40
DM00	DM00	longitudinal mixer input	aft	%	0	100
DM01	DM01	lateral mixer input	right	%	0	100
DM02	DM02	directional mixer input	right pedal	%	0	100
MIXA	DMIXA	lateral mixer input	right	in	0	2.1
MIXE	DMIXE	longitudinal mixer input	aft	in	0	2.1
MIXR	DMIXR	directional mixer input	right pedal	in	0	1.9
DP00	DP00	forward primary servo input		%	0	100
DP01	DP01	lateral primary servo input		%	0	100
DP03	DP02	aft primary servo input		%	0	100
PAFT	PSAFT	aft primary servo input		in	0	4.1
PFWD	PSFWD	forward primary servo input		in	0	3.3
PLAT	PSLAT	lateral primary servo		in	0	4.3
DS00	SASE	longitudinal SAS output	nose up	%	0	100
DS01	SASA	lateral SAS output	turn right	%	0	100
DS02	SASR	directional SAS output	nose right	%	0	100
R021	TRIP	tail rotor impress pitch	left pedal	%	0	100
DA00	PITCHATT	pitch attitude	nose up	deg	-50	50
DA01	ROLLATT	roll attitude	turn right	deg	-100	100
DA02	HEADING	magnetic heading	nose rightnose	deg	0	360
DR00	PITCHR8	pitch rate gyro	up	deg/sec	-50	50
DR01	ROLLR8	roll rate gyro	turn right	deg/sec	-50	50
DR02	YAWR8	yaw rate gyro	nose right	deg/sec	-50	50
DAC0	PITCHACC	pitch angular accelerometer	nose up	deg/sec2	-600	600
DAC1	ROLLACC	roll angular accelerometer	turn right	deg/sec2	-200	200
DAC2	YAWACC	yaw angular accelerometer	nose right	deg/sec2	-100	100
DL00	AMGX	x accelerometer	forward	g	-2	2
DL01	AMGY	y accelerometer	right	g	-2	2
DL02	AMGZ	z accelerometer	up	g	-2	4
DAA0	ALPHA	boom alpha vane	nose up	deg	-100	100
DSS0	BETA	boom sideslip vane	nose left	deg	-100	100
V001	V001	boom dynamic pressure		in Hg	0	2
H001	H001	boom static pressure		in Hg	20	32
H003	RALT	radar altimeter		ft	0	1500
T100	T100	stagnation temperature		deg C	-20	50
VX03	LSSX	LASSIE forward airspeed	forward	kts	-35	165
VY03	LSSY	LASSIE lateral airspeed	right	kts	-50	50
VZ03	LSSZ	LASSIE vertical airspeed	up	ft/min	-300	2000
HKLD	HKLD	hook load		lbs	0	10000

TABLE 2. TRENDS SIGNALS AND VARIABLES (CONTINUED)

(b) Group LD: Load Sensors

Item code	Alias	Description	Positive direction	Units	Range	
					Min	Max
AL01	AMGXL	load x accelerometer	forward	g	-2.5	2.5
AL02	AMGYL	load y accelerometer	right	g	-2.5	2.5
AL03	AMGZL	load z accelerometer	up	g	-12.5	12.5
DAL1	PANGL	load pitch inclinometer	nose up	counts *	0	4096
DAL2	RANGL	load roll inclinometer	roll right	counts *	0	4096
DAL3	YAWANG	load magnetic heading	nose right	deg	0	360
DRL1	PITCHR8L	load pitch rate gyro	nose DOWN	deg/sec	-60	60
DRL2	ROLLR8L	load roll rate gyro	roll right	deg/sec	-90	90
DRL3	YAWR8L	load yaw rate gyro	nose right	deg/sec	-120	120

* conversion of inclinometers to deg = sin −1(counts/2048 – 1)

TABLE 2. TRENDS SIGNALS AND VARIABLES (CONTINUED)

(c) Group DP: Derived Parameters

Alias	Item code	Description *, +	Positive direction	Units	Range	
					Min	Max
XAIN	XAIN	lateral stick position	turn right	in		
XBIN	XBIN	longitudinal stick position	forward	in		
XPIN	XPIN	pedal position	nose right	in		
XCIN	XCIN	collective position	up	in		
XABST	ABST	lateral boost servo output	turn right	in		
XEBST	EBST	longitudinal boost servo output	forward	in		
XPBST	PBST	pedal boost servo output	turn right	in		
XCBST	CBST	collective boost servo output	up	in		
DMIXC	MIXC	collective mixer input	up	in		
PSTRIN	PSTR	tail rotor servo output	left pedal	in		
DR00S	DR0S	smoothed pitch rate *	nose up	deg/sec		
DR01S	DR1S	smoothed roll rate *	right turn	deg/sec		
DR02S	DR2S	smoothed yaw rate *	nose right	deg/sec		
DR00D	DR0D	derivative of DR00S	nose up	deg/sec2		
DR01D	DR1D	derivative of DR01S	right turn	deg/sec2		
DR02D	DR2D	derivative of DR02S	nose right	deg/sec2		
DL00S	DL0S	smoothed x accelerometer	forward	g		
DL01S	DL1S	smoothed y accelerometer	right	g		
DL02S	DL2S	smoothed z accelerometer	up	g		
DV1SNX	X1DD	x inertial cg acceleration	forward	ft/sec2		
DV1SNY	Y1DD	y inertial cg acceleration	right	ft/sec2		
DV1SNZ	Z1DD	z inertial cg acceleration	down	ft/sec2		
VICB	IASX	boom indicated airspeed		kts		
VCALB	CASX	boom calibrated airspeed		kts		
VEB	EASX	boom equivalent airspeed		kts		
VTB	VTBX	boom true airspeed		kts		
U1	U1XX	cg x body velocity, boom data	forward	ft/sec		
V1	V1XX	cg y body velocity, boom data	right	ft/sec		
W1	W1XX	cg z body velocity, boom data	down	ft/sec		
VT	VTXX	TAS from boom and/or LASSIE		ft/sec		
LSSXC	LSSU	calibrated LASSIE x velocity	forward	kts		
LSSYC	LSSV	calibrated LASSIE y velocity	right	kts		
VTBS	VTBS	TAS from smoothed boom data*		kts		
VICBS	IASS	IAS from smoothed boom data*		kts		
HDB	HDBX	density altitude from boom data		ft		
HDBS	HDBS	density alt frm smoothed data *		ft		
HMHRWS	HPXX	pressure alt frm smoothed data*		ft		
HMHRWD	HPDX	pressure altitude rate +	up	ft/sec		
H003D	HRDX	radar altimeter rate +	up	ft/sec		
TA	TAXX	ambient temperature		deg C		
TASMTH	AATS	TA from smoothed boom data *		deg C		

TABLE 2. TRENDS SIGNALS AND VARIABLES (CONTINUED)

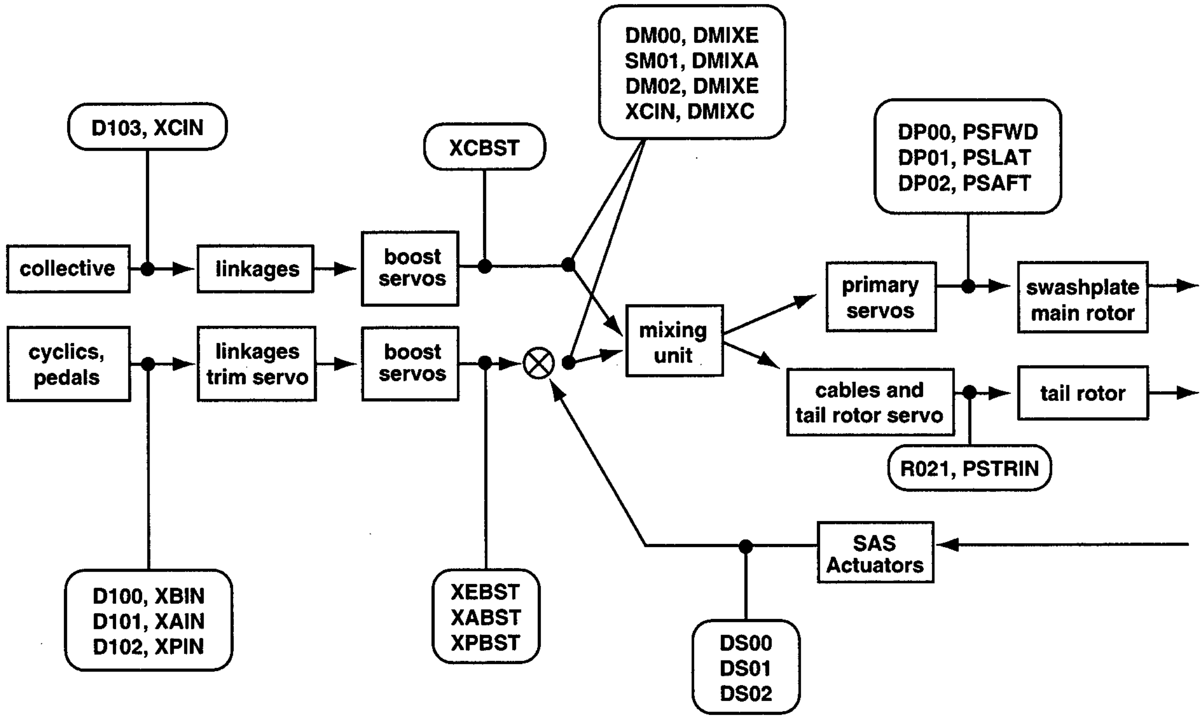
(c) Group DP, cont.

Alias	Item code	Description	Positive direction	Units	Range	
					Min	Max
AL01S	AL1S	Smoothed Load x Accelerometer *	Forward	g		
AL02S	AL2S	Smoothed Load y Accelerometer *	Right	g		
AL03S	AL3S	Smoothed Load z Accelerometer *	Up	g		
DV2S2X	X2DD	Load cg Body x Acceleration	Forward	ft/sec2		
DV2S2Y	Y2DD	Load cg Body y Acceleration	Right	ft/sec2		
DV2S2Z	Z2DD	Load cg Body z Acceleration	Down	ft/sec2		
DAL3C	PS2C	Load Heading, Transient Removed	Nose Right	deg		
DAL3CC	PS2C	Continuous Load Heading	Nose Right	deg		
PS2P	PS2P	Load Heading – HC Heading		deg		
DRL1S	P2SX	Smoothed Load Pitch Rate *	Nose DOWN	deg/sec		
DRL2S	MQ2S	Smoothed Load Roll Rate *	Roll Right	deg/sec		
DRL3S	R2SX	Smoothed Load Yaw Rate *	Nose Right	deg/sec		
DRL1D	P2DX	Derivative of DRL1S	Nose DOWN	deg/sec2		
DRL2D	MQ2D	Derivative of DRL2S	Roll Right	deg/sec2		
DRL3D	R2DX	Derivative of DRL2S	Nose Right	deg/sec2		
P2	P2XX	De-Biased Load Roll Rate	Roll Right	deg/sec		
Q2	Q2XX	De-Biased Load Pitch Rate	Nose UP	deg/sec		
R2	R2XX	De-Biased Load Yaw Rate	Nose Right	deg/sec		
P2P	P2PX	Load Roll Rate in HC Heading Axes	Roll Right	deg/sec		
Q2P	Q2PX	Load Pitchr8 in HC Heading Axes	Nose UP	deg/sec		

Notes:

* cutoff frequency for smoothing filter = 2.5 Hz

+ cutoff frequency for smoothing filter = .25 Hz



SIGNAL	ITEM CODE	UNITS	MULTIPLY BY	CONVERT TO	NEW SIGNAL
Cockpit sticks					
Longitudinal	D100	percent	.1125	inches	XBIN
Lateral	D101	percent	.095625	inches	XAIN
Pedal	D102	percent	.056875	inches	XPIN
Collective	D103	percent	.10625	inches	XCIN
Boost servo outputs					
Longitudinal	XBIN	inches	.21	inches	XEBST
Lateral	XCIN	inches	.24	inches	XABST
Pedal	XPIN	inches	.36	inches	XPBST
Collective	XCIN	inches	.20	inches	XCBST
Mixer inputs					
Longitudinal	DM00	percent	.02108	inches	DMIXE
Lateral	DM01	percent	.02065	inches	DMIXA
Directional	DM02	percent	.0189	inches	DMIXR
Collective	XCIN	percent	.2025	inches	DMIXC
Primary servo outputs					
Forward	DP00	percent	.0406	inches	PSFWD
Lateral	DP01	percent	.0327	inches	PSLAT
Aft	DP03	percent	.0429	inches	PSAFT
Tail rotor	R021	percent	.0308	inches	PSTRIN

Figure 30. Control system sensor locations and and signal scalings.

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT

Flight #: 151 **Date of Flight:** 3-May-95

Remarks: hover, freq sweeps all axes, 1K plate load
FPS on

Flight Personnel:

Pilot: G. Tucker Co-Pilot: R. Simmons

Crew Chief: J. Phillips Aircrew:

Weather:

Winds: calm **Temperature** 57.0 deg F

Altimeter Setting (in Hg): 30.04 13.9 deg C

Aircraft Configuration:

ref gross weight 14601 lbs

ref x-moment 5307900 ft-lbs

ref cg station 363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Times start	stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
2	15102	14:48:26	14:50:20	pedal sweep	IK plate	hover		1,2 on	on	*2110
3	15103	14:51:40	14:51:51	pedal doublet		hover		1,2 on	on	*2060
4	15104	14:52:22	14:54:15	coll sweep		hover		1,2 on	on	*2040
5	15105	14:55:25	14:57:10	coll sweep		hover		1,2 on	on	*1990
						hover		1,2 on	on	
7	15107	14:59:00	14:59:15	coll doublet	1K plate	hover		1,2 on	on	*1930
8	15108	14:59:58	15:01:53	lon'l sweep		hover		1,2 on	on	*1920
9	15109	15:02:37	15:04:20	lon'l sweep		hover		1,2 on	on	*1870
10	15110	15:05:15	15:06:58	lon'l sweep		hover		1,2 on	on	*1820
11	15111	15:07:30	15:07:50	lon'l doublet		hover		1,2 on	on	*1790
12	15112	15:09:23	15:11:07	lateral sweep	1K plate	hover		1,2 on	on	*1760
13	15113	15:11:48	15:13:06	lateral sweep		hover		1,2 on	on	*1720
14	15114	15:14:17	15:16:10	lateral sweep		hover		1,2 on	on	1680
15	15115	15:17:17	15:17:30	lateral doublet		hover		1,2 on	on	*1630
16	15116	15:18:23	15:20:07	coll sweep		hover		1,2 on	on	*1510
17	15117	15:20:40	15:22:25	pedal sweep	1K plate	hover		1,2 on	on	1570

* = est'd

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 153 **Date of Flight:** 23-Jun-95

Remarks: 4-axis freq sweeps at 80kts, 1Klbs internal load
FPS on

Flight Personnel:

Pilot: G. Tucker Co-Pilot: W. Hindson

Crew Chief: Aircrew:

Weather:

Winds: calm

Altimeter Setting (in Hg): 30.001

Temperature 70 deg F
21.1 deg C

Aircraft Configuration:

ref gross weight 15575 lbs
x-moments 5661513 ft-lbs
ref cg sta 363.5 in

Load Weights (lbs)

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Times start	Record Times stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	15301	15:09:11	15:09:54	control throws			on ground			
2	15302	15:24:25	15:26:14	lon'l sweep	none	80	1000	1,2 on	on	2250
3	15303	15:27:29	15:29:26	coll sweep		80	1000	1,2 on	on	2210
4	15304	15:30:49	15:32:36	coll sweep		80	1000	1,2 on	on	2180
5	15305	15:34:58	15:36:43	lon'l sweep		80	1000	1,2 on	on	2130
6	15306	15:37:54	15:39:31	lon'l sweep	none	80	1000	1,2 on	on	2090
7	15307	15:39:59	15:40:05	lon'l doublet		80	1000	1,2 on	on	2080
8	15308	15:41:32	15:43:17	lateral sweep		80	1000	1,2 on	on	2050
9	15309	15:44:47	15:46:29	lateral sweep		80	1000	1,2 on	on	2010
10	15310	15:48:07	15:49:47	lateral sweep		80	1000	1,2 on	on	1980
11	15311	15:50:07	15:50:23	lateral doublet	none	80	1000	1,2 on	on	1950
12	15312	15:51:57	15:52:09	lateral doublet		80	1000	1,2 on	on	1940
13	15313	15:54:08	15:55:52	coll sweep		80	1000	1,2 on	on	1900
14	15314	15:56:53	15:57:06	coll doublet		80	1000	1,2 on	on	1890
15	15315	15:58:04	15:59:48	pedal sweep		80	1000	1,2 on	on	1840
16	15316	16:02:00	16:03:38	pedal sweep	none	80	1000	1,2 on	on	1810
18	15318	16:06:31	16:08:24	pedal sweep		80	1000	1,2 on	o	1760

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TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 154 **Date of Flight:** 10-Aug-95

Remarks: lon,lat sweeps at 80kts, 1K internal load
FPS off

Flight Personnel:

Pilot: G. Tucker   Co-Pilot: M. Dearing

Crew Chief: Aircrew:

Weather:

Winds: calm   **Temperature** 59 deg F

Altimeter Setting (in Hg): 29.81   15 deg C

Aircraft Configuration:

ref gross weight	15575 lbs
ref x-moments	5661513 ft-lbs
ref cg sta	363.4 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL   **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Times start	stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	15401	0:00:30	0:01:10	control throws			on ground			
2	15402	0:52:09	0:54:03	lon'l sweep	none	80	1000	1,2 on	off	1960
3	15403	0:56:40	0:58:32	lon'l sweep	none	80	1000	1,2 on	off	1900
4	15404	1:00:50	1:02:41	lon'l sweep	none	80	1000	1,2 on	off	1840
5	15405	1:05:24	1:07:21	lon'l sweep	none	80	1000	1,2 on	off	1770
6	15406	1:09:25	1:09:49	lon'l doublet	none	80	1000	1,2 on	off	1720
7	15407	1:10:38	1:10:56	lon'l doublet	none	80	1000	1,2 on	off	1710
8	15408	1:12:49	1:14:25	lon'l sweep	none	80	1000	1,2 on	off	1680
9	15409	1:17:11	1:19:22	lon'l sweep	none	80	1000	1,2 on	off	1610
10	15410	1:21:00	1:21:22	lon'l doublet	none	80	1000	1,2 on	off	1580
11	15411	1:24:32	1:26:22	lateral sweep	none	80	1000	1,2 on	off	1530
12	15412	1:28:42	1:30:21	lateral sweep	none	80	1000	1,2 on	off	1480
13	15413	1:32:04	1:34:02	lateral sweep	none	80	1000	1,2 on	off	1430
14	15414	1:35:33	1:37:18	lateral sweep	none	80	1000	1,2 on	off	1390

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 156 **Date of Flight:** 23-Jan-96
Remarks: trims, stps, dblts at {0,20,40,60,80,100,120} kts w 4K block load

Flight Personnel:

Pilot: G. Tucker Co-Pilot: R. Simmons
Crew Chief: J. Phillips Aircrew:

Weather:

Winds: 5-7kts @ 120 deg **Temperature** 45 deg F
Altimeter Setting (in Hg): 30.37 7.2 deg C

Aircraft Configuration:

ref gross weight 14601 lbs
ref x-moment 5307900 ft-lbs
Center of Gravity: 363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Length secs		Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
15	15615	17:01:40	17:01:50	trim	4K block	hover		1,2 on	off	*2040
16	15616	17:04:57	17:05:30	trim		20		1,2 on	off	*1990
17	15617	17:06:10	17:06:18	long'l step		20		1,2 on	off	1980
18	15618	17:06:55	17:07:05	lateral sweep		20		1,2 on	off	1970
19	15619	17:07:35	17:07:49	pedal step		20		1,2 on	off	1960
20	15620	17:10:40	17:10:50	lon'l doublet	4K block	20		1,2 on	off	1950
21	15621	17:11:23	17:11:33	lateral doublet		20		1,2 on	off	1940
22	15622	17:12:00	17:12:15	pedal doublet		20		1,2 on	off	1930
23	15623	17:12:30	17:12:41	pedal doublet		20		1,2 on	off	*1925
24	15624	17:16:40	17:16:50	trim		40		1,2 on	off	*1870
25	15625	17:20:18	17:20:31	long'l step	4K block	40		1,2 on	off	1810
26	15626	17:21:00	17:21:10	lateral step		40		1,2 on	off	1800
27	15627	17:21:25	17:21:36	pedal step		40		1,2 on	off	1790
28	15628	17:24:49	17:24:59	long'l doublet		40		1,2 on	off	1740
29	15629	17:27:41	17:27:51	pedal doublet		40		1,2 on	off	1700
30	15630	17:31:20	17:31:32	lateral doublet	4K block	40		1,2 on	off	1650
31	15631	17:35:11	17:35:21	trim		60		1,2 on	off	*1585
32	15632	17:36:24	17L36:34	long'l step		60		1,2 on	off	1570
33	15633	17:38:07	17:38:17	lateral step		60		1,2 on	off	1550
34	15634	17:39:31	17:39:41	pedal step		60		1,2 on	off	1530

* = est'd

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Filename	Record Times start	Record Times stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
35	15635	17:41:02	17:41:12	long'l step	4K block	60		1,2 on	off	1520
36	15636	17:42:44	17:42:53	lateral doublet		60		1,2 on	off	1490
37	15637	17:43:31	17:43:41	pedal doublet		60		1,2 on	off	1480
38	15638	17:46:28	17:46:38	trim		80		1,2 on	off	*1450
39	165639	17:48:00	17:48:10	long'l step		80		1,2 on	off	1430
40	15640	17:48:59	17:49:09	lateral step	4K block	80		1,2 on	off	1410
41	15641	17:49:47	17:49:59	pedal step		80		1,2 on	off	1390
42	15642	17:51:29	17:51:39	long'l doublet		80		1,2 on	off	1380
43	15643	17:52:55	17:53:05	lateral doublet		80		1,2 on	off	1360
44	15644	17:54:33	17:54:44	pedal doublet		80		1,2 on	off	1340
45	15645	17:56:30	17:56:40	trim	4K block	100		1,2 on	off	*1320
46	15646	17:58:26	17:58:36	long'l step		100		1,2 on	off	1290
47	15647	17:59:24	17:59:34	lateral step		100		1,2 on	off	1280
48	15648	18:01:33	18:01:43	pedal step		100		1,2 on	off	1250
49	15649	18:02:39	18:02:49	long'l doublet		100		1,2 on	off	1240
50	15650	18:04:39	18:04:49	lateral doublet	4K block	100		1,2 on	off	1210
51	15651	18:05:18	18:05:28	pedal doublet		100		1,2 on	off	1190
53	15653	18:10:20	10:10:30	trim		120		1,2 on	off	*1125
54	15654	18:11:03	18:11:13	long'l step		120		1,2 on	off	1110
55	15655	18:12:37	18:12:47	lateral step	4K block	120		1,2 on	off	1090
56	15656	18:13:27	18:13:37	pedal step		120		1,2 on	off	1080
57	15657	18:15:37	18:15:47	long'l doublet		120		1,2 on	off	1040
58	15658	18:16:14	18:16:24	lateral doublet		120		1,2 on	off	11030
59	15659	18:17:43	18:17:53	pedal doublet		120		1,2 on	off	1010
										* = est'd

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TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 157 **Date of Flight:** 20-Mar-96

Remarks: airspd/altimeter calibration checks
no load

Flight Personnel:

Pilot: G. Tucker Co-Pilot: M. Dearing

Crew Chief: Aircrew:

Weather:

Winds: calm **Temperature**

Altimeter Setting (in Hg):

Aircraft Configuration:

	Start	
ref gross weight	14401	lbs
ref x-moment	5251500	ft-lbs
ref cg station	364.7	in

Load Weights (lbs)

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	15701	15:10:21	15:10:42	trim	none	80				1820
2	15702	15:12:33	15:12:54	trim		80				1780
3	15703	15:14:23	15:14:48	trim		60				1760
4	15704	15:17:54	15:18:16	trim		60				1730
5	15705	15:19:44	15:20:11	trim		40				1710
6	15706	15:21:42	15:22:05	trim	none	40				1680
7	15707	15:24:33	15:25:00	trim		20				1650
8	15708	15:27:12	15:27:35	trim		20				1610
9	15709	15:30:23	15:30:59	trim		10				1580
10	15710	15:33:42	15:34:16	trim		10				1540
11	15711	15:36:31	15:36:56	trim	none	30				1500
12	15712	15:38:59	15:39:27	trim		30				1470
13	15713	15:41:14	15:41:40	trim		50				1450
14	15714	15:43:19	15:43:44	trim		50				1430
15	15715	15:45:19	15:45:39	trim		70				1400
16	15716	15:47:02	15:47:19	trim	none	70				1380
17	15717	15:48:40	15:49:00	trim		90				1360
18	15718	15:50:43	15:51:00	trim		90				1330
19	15719	15:52:16	15:52:39	trim		110				1330
20	15720	15:53:57	15:54:24	trim		110				1300

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TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
21	15721	15:55:59	15:55:44	trim	none	130				1270
22	15722	15:57:25	15:57:39	trim		130				1250
23	15723	15:59:02	15:59:17	trim		120				1230
24	15724	16:00:37	16:00:51	trim		120				1210
25	15725	16:02:14	16:02:30	trim		100				1190
26	15726	16:03:54	16:04:10	trim	none	100				1170
27	15727	16:08:13	16:08:24	trim		hover	20			
28	15728	16:09:33	16:09:45	trim		hover	10			
29	15729	16:10:55	16:11:07	trim		hover	5			
30	15730	16:12:00	16:12:12	trim		hover	30			
31	15731	16:13:08	16:13:20	trim	none	hover	40			
32	15732	16:14:37	16:14:46	trim		hover	50			
33	15733	16:15:36	16:15:50	trim		hover	60			
34	15734	16:17:12	16:17:26	trim		hover	80			
35	15735	16:18:36	16:20:22	trim		hover	100			
36	15736	16:20:25	16:20:38	trim	none	hover	120			
37	15737	16:22:01	16:22:17	10deg pitch up		hover				
38	15738	16:23:01	16:23:23	10deg pitch dwn		hover				
39	15739	16:24:08	16:24:24	10 deg roll lft		hover				
40	15740	16:24:26	16:25:11	10 deg roll rt		hover				
41-9	15741-9	16:33:10	16:42:12	control throws	none		on ground	1 on	off	

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 158 **Date of Flight:** 25-Apr-96
Remarks: steps and doublets at {hover, 60, 80, 100} kts w 4k block load
22 sensor signals - no acceler'rs, alfa, beta, radar alt, static P

Flight Personnel:
Pilot: G. Tucker Co-Pilot: R. Simmons
Crew Chief: J. Phillips Aircrew:

Weather:
Winds: 5kts @ 120 deg **Temperature** 60 deg F
Altimeter Setting (in Hg): 30.2 15.6 deg C

Aircraft Configuration:

ref gross weight 14601 lbs
ref x-moment 5307900 ft-lbs
ref cg station 363.6 in

Load Weights (lbs)

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Times Start	Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1 thru 11	15801-11	14:47:39	14:55:54	control throws			on ground			
12	15812	15:18:14	15:18:24	trim	4k block	hover	OGE	1,2 on	on	2230
13	15813	15:19:33	15:19:46	long'l step		hover	OGE	1,2 on	on	2210
14	15814	15:20:23	15:20:36	long'l doubler		hover	OGE	1,2 on	on	2200
15	15815	15:21:02	15:21:14	long'l step		hover	OGE	1,2 on	on	2190
16	15816	15:21:53	15:22:05	long'l doubler	4k block	hover	OGE	1,2 on	on	2180
17	15817	15:22:39	15:22:51	lateral step		hover	OGE	1,2 on	on	2170
18	15818	15:23:27	15:23:40	lateral doublet		hover	OGE	1,2 on	on	2160
19	15819	15:24:10	15:24:22	lateral step		hover	OGE	1,2 on	on	2150
20	15820	15:25:03	15:25:15	lateral doublet		hover	OGE	1,2 on	on	2140
21	15821	15:25:47	15:25:59	yaw step	4k block	hover	OGE	1,2 on	on	2130
22	15822	15:26:33	15:26:46	yaw doublet		hover	OGE	1,2 on	on	2120
23	15823	15:27:11	15:27:25	yaw step		hover	OGE	1,2 on	on	2110
24	15824	15:27:57	15:28:10	yaw doublet		hover	OGE	1,2 on	on	2100
25	15825	15:28:52	15:29:04	coll step		hover	OGE	1,2 on	on	2080
26	15826	15:29:56	15:30:08	coll doublet	4k block	hover	OGE	1,2 on	on	2070
27	15827	15:30:47	15:31:01	coll step		hover	OGE	1,2 on	on	2060
28	15828	15:31:41	15:31:54	coll doublet		hover	OGE	1,2 on	on	2040
29	15829	15:38:20	15:38:33	trim		80	1000	1,2 on	on	1950
30	15830	15:39:44	15:39:56	long'l step		80	1000	1,2 on	on	1930

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Filename	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
31	15831	15:41:18	15:41:31	long'l doublet	4k block	80	1000	1,2 on	on	1920
32	15832	15:42:10	15:42:23	long'l doublet		80	1000	1,2 on	on	1910
33	15833	15:43:11	15:43:25	long'l doublet		80	1000	1,2 on	on	1900
34	15834	15:44:43	15:44:55	lateral step		80	1000	1,2 on	on	1870
35	15835	15:46:00	15:46:13	lateral doublet		80	1000	1,2 on	on	1860
36	15836	15:47:08	15:47:21	lateral doublet	4k block	80	1000	1,2 on	on	1850
37	15837	15:48:22	15:48:35	lateral doublet		80	1000	1,2 on	on	1840
38	15838	15:49:46	15:49:59	pedal step		80	1000	1,2 on	on	1820
39	15839	15:50:50	15:51:03	pedal doublet		80	1000	1,2 on	on	1810
40	15840	15:52:18	15:52:30	pedal step		80	1000	1,2 on	on	1790
41	15841	15:53:51	15:54:04	pedal doublet	4k block	80	1000	1,2 on	on	1770
42	15842	15:55:48	15:56:01	coll step		80	1000	1,2 on	on	1760
43	15843	15:57:24	15:57:37	coll doublet		80	1000	1,2 on	on	1740
44	15844	15:58:52	15:59:08	coll step		80	1000	1,2 on	on	1730
45	15845	16:00:00	16:00:13	coll doublet		80	1000	1,2 on	on	1710
46	15846	16:02:55	16:03:08	trim	4k block	60	1000	1,2 on	on	1670
47	15847	16:04:03	16:04:13	long'l step		60	1000	1,2 on	on	1660
48	15848	16:05:11	16:05:24	long'l doublet		60	1000	1,2 on	on	1650
49	15849	16:06:51	16:07:14	long'l step		60	1000	1,2 on	on	1640
50	15850	16:08:13	16:08:26	long'l doublet		60	1000	1,2 on	on	1620
51	15851	16:10:51	16:11:03	lateral step	4k block	60	1000	1,2 on	on	1590
52	15852	16:11:37	16:11:49	lateral doublet		60	1000	1,2 on	on	1580
53	15853	16:12:59	16:13:12	lateral step		60	1000	1,2 on	on	1570
54	15854	16:14:39	16:14:53	lateral doublet		60	1000	1,2 on	on	1550
55	15855	16:15:54	16:16:06	pedal step		60	1000	1,2 on	on	1540
56	15856	16:17:15	16:17:28	pedal doublet	4k block	60	1000	1,2 on	on	1520
57	15857	16:18:29	16:18:39	pedal step		60	1000	1,2 on	on	1510
58	15858	16:20:06	16:20:18	pedal doublet		60	1000	1,2 on	on	1490
59	15859	16:21:40	16:21:51	coll step		60	1000	1,2 on	on	1470
60	15860	16:22:50	16:23:03	coll doublet		60	1000	1,2 on	on	1460
61	15861	16:24:03	16:24:16	coll step	4k block	60	1000	1,2 on	on	1440
62	15862	16:25:07	16:25:20	coll doublet		60	1000	1,2 on	on	1430
63	15863	16:28:23	16:28:36	trim		60	1000	1,2 on	on	1390
64	15864	16:29:14	16:29:26	long'l step		100	1000	1,2 on	on	1380
65	15865	16:30:35	16:30:48	long'l doublet		100	1000	1,2 on	on	1360
66	15866	16:31:40	16:31:52	long'l step	4k block	100	1000	1,2 on	on	1350
67	15867	16:32:35	16:32:48	long'l doublet		100	1000	1,2 on	on	1340
68	15868	16:33:47	16:34:00	lateral step		100	1000	1,2 on	on	1330
69	15869	16:34:50	16:35:02	lateral doublet		100	1000	1,2 on	on	1320
70	15870	16:35:47	16:36:00	lateral step		100	1000	1,2 on	on	1300
72	15872	16:38:07	16:38:20	lateral doublet	4k block	100	1000	1,2 on	on	1270
73	15873	16:39:25	16:39:40	pedal step		100	1000	1,2 on	on	1260
74	15874	16:40:19	16:40:33	pedal doublet		100	1000	1,2 on	on	1240
75	15875	16:41:43	16:41:55	pedal step		100	1000	1,2 on	on	1230

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Counter	Record Times Sdtart	Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Weight (lbs)
76	15876	16:42:48	16:43:00	pedal doublet	4K block	100	1000	1,2 on	on	1230
77	15877	16:44:07	16:44:20	coll step		100	1000	1,2 on	on	1220
78	15878	16:44:51	16:45:04	coll doublet		100	1000	1,2 on	on	1200
79	15879	16:45:49	16:46:03	coll step		100	1000	1,2 on	on	1190
80	15880	16:47:19	16:47:32	coll doublet		100	1000	1,2 on	on	1170
81	15881	16:48:39	16:48:52	trim	4K block	100	1000	1,2 on	on	1150
82	15882	16:51:54	16:52:06	trim		40	1000	1,2 on	on	1110
83-93	15883-93	16:08:18	17:14:51	control throws	none		on ground			

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 159 **Date of Flight:** 6-Jun-96
Remarks: hover records w 4k block load

Flight Personnel:

Pilot: G. Tucker Co-Pilot: M. Dearing
Crew Chief: J. Phillips Aircrew:

Weather:

Winds: calm **Temperature** 64.5 deg F
Altimeter Setting (in Hg): 29.92 18.1 deg C

Aircraft Configuration:

ref gross weight 14601 lbs
ref x-moment 5307900 ft-lbs
ref cg station 363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100Hz

Record Number	Trends Counter	Record Times Start	Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1thru11	15901-11	0:41:46	0:08:59	control throws			on ground	1 on	off	
12	15912	0:42:55	O:43:06	trim	4k block	hover	OGE	1,2 on	off	2030
13	15913	0:44:41	0:46:58	pedal sweep		hover	OGE	1,2 on	off	1990
14	15914	0:47:46	0:49:29	pedal sweep		hover	OGE	1,2 on	off	1940
15	15915	0:49:54	0:51:53	pedal sweep		hover	OGE	1,2 on	off	1880
16	15916	0:52:11	0:52:22	pedal step		hover	OGE	1,2 on	off	1860
17	15917	0:52:46	0:52:59	pedal doublet	4k block	hover	OGE	1,2 on	off	1860
18	15918	0:53:25	0:53:34	pedal step		hover	OGE	1,2 on	off	1830
19	15919	0:53:58	0:54:09	pedal doublet		hover	OGE	1,2 on	off	1820
20	15920	0:56:17	0:56:49	coll step		hover	OGE	1,2 on	off	1790
21	15921	0:57:15	0:57:35	coll doublet		hover	OGE	1,2 on	off	1760
22	15922	0:58:06	0:58:18	coll step	4k block	hover	OGE	1,2 on	off	1750
23	15923	0:58:44	0:59:00	coll doublet		hover	OGE	1,2 on	off	1740
24	15924	0:59:43	1:00:00	coll doublet		hover	OGE	1,2 on	off	1710
25	15925	1:00:45	1:02:30	coll sweep		hover	OGE	1,2 on	off	1690
26	15926	1:03:07	1:04:52	coll sweep		hover	OGE	1,2 on	off	1650
27	15927	1:05:34	1:07:06	coll sweep	4k block	hover	OGE	1,2 on	off	1600
28	15928	1:08:10	1:09:53	long'l sweep		hover	OGE	1,2 on	off	1550
29	15929	1:10:41	1:11:19	long'l sweep		hover	OGE	1,2 on	off	1510
30	15930	1:12:05	1:12:22	bad record		hover	OGE	1,2 on	off	1480

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Counter	Record Times Start	Record Times Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
31	15931	1:12:55	1:13:30	long'l sweep	4k block	hover	OGE	1,2 on	off	1460
32	15932	1:13:54	1:14:34	Bad Record		hover	OGE	1,2 on	off	1440
33	15933	1:15:00	1:16:41	long'l sweep		hover	OGE	1,2 on	off	1420
34	15934	1:17:10	1:18:53	long'l sweep		hover	OGE	1,2 on	off	1380
35	15935	1:19:21	1:19:31	long'l step		hover	OGE	1,2 on	off	1350
36	15936	1:20:22	1:20:36	long'l doublet		hover	OGE	1,2 on	off	1350
37	15937	1:21:02	1:21:13	long'l step	4k block	hover	OGE	1,2 on	off	1320
38	15938	1:21:35	1:21:51	long'l doublet		hover	OGE	1,2 on	off	1300
39	15939	1:22:36	1:24:24	lateral sweep		hover	OGE	1,2 on	off	1290
40	15940	1:24:54	1:26:31	lateral sweep		hover	OGE	1,2 on	off	1240
41	15941	1:27:14	1:28:48	lateral sweep		hover	OGE	1,2 on	off	1210
42	15942	1:29:20	1:29:34	lateral step	4k block	hover	OGE	1,2 on	off	1180
43	15943	1:29:56	1:30:19	lateral doublet		hover	OGE	1,2 on	off	1170
44	15944	1:30:46	1:31:02	lateral step		hover	OGE	1,2 on	off	1140
45	15945	1:31:40	1:31:58	lateral doublet		hover	OGE	1,2 on	off	1090
47 - 57	15947-57	2:13:12	2:19:31	control throws	none		on ground	1 on	off	

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 160 **Date of Flight:** 19-Jul-96
Remarks: 89kts lon, lat axis sweeps, 1k plate load
24 HC sensor signals (no x-y acceler'rs, alfa/beta, radar h, static P)

Flight Personnel:
Pilot: R. Simmons Co-Pilot: G. Tucker
Crew Chief: J. Phillips Aircrew:

Weather:
Winds: 14-20kts @ 330 deg **Temperature** 78.8 deg F
Altimeter Setting (in Hg): 30.05 26.0 deg C

Aircraft Configuration:

ref gross weight 14601 lbs
ref x-moment 5307900 ft-lbs
ref cg station 363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Times Start	Record Times Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1 thru 11	16001-11	18:02:59	18:09:41	control throws			on ground	1 on	off	
12	16012	19:03:50	19:04:07	trim	1k plate	0	OGE	1,2 on	off	1790
13	16013	19:12:06	19:12:22	trim		80	1500	1,2 on	off	1690
14	16014	19:14:06	19:15:51	long'l sweep		80	1500	1,2 on	off	1650
15	16015	19:17:02	19:18:46	long'l sweep		80	1500	1,2 on	off	1610
16	16016	19:20:28	19:22:11	long'l sweep	1k plate	80	1500	1,2 on	off	1580
17	16017	19:23:45	19:24:12	long'l step		80	1500	1,2 on	off	1560
18	16018	19:24:57	19:25:14	long'l step		80	1500	1,2 on	off	1530
19	16019	19:26:00	19:26:17	long'l doublet		80	1500	1,2 on	off	1530
20	16020	19:26:44	19:26:59	long'l step		80	1500	1,2 on	off	1520
21	16021	19:27:43	19:27:59	long'l doublet	1k plate	80	1500	1,2 on	off	1500
22	16022	19:29:11	19:30:09	lateral sweep		80	1500	1,2 on	off	1460
23	16023	19:32:20	19:34:03	lateral sweep		80	1500	1,2 on	off	1440
24	16024	19:34:43	19:36:06	lateral sweep		80	1500	1,2 on	off	1410
25	16025	19:38:20	19:38:35	lateral step		80	1500	1,2 on	off	1380
26	16026	19:39:00	19:39:15	lateral doublet	1k plate	80	1500	1,2 on	off	1370
27	16027	19:40:21	19:40:34	lateral step		80	1500	1,2 on	off	1350
28	16028	19:41:09	19:41:25	lateral doublet		80	1500	1,2 on	off	1340
29	16029	19:42:42	19:44:24	long'l sweep		80	1500	off	off	1320
30	16030	19:45:35	19:47:21	long'l sweep		80	1500	off	off	1280

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TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Trends Counter	Record Times Start	Stop	Maneuver	Load	Airspeed kts	Altitude ft	SAS	FPS	Fuel Wt. (pounds)
31	16031	19:48:54	19:50:40	long'l sweep	1k plate	80	1500	off	off	1250
32	16032	19:51:12	19:51:28	long'l step		80	1500	off	off	1230
33	16033	19:53:04	19:53:23	long'l doublet		80	1500	off	off	1210
34	16034	19:53:55	19:54:07	long'l step		80	1500	off	off	1200
35	16035	19:54:48	19:55:08	long'l doublet		80	1500	off	off	1180
36	16036	19:56:39	19:58:29	lateral sweep	1k plate	80	1500	off	off	1150
37	16037	19:59:07	20:00:46	lateral sweep		80	1500	off	off	1130
38	16038	20:02:49	20:04:38	lateral sweep		80	1500	off	off	1070
39	16039	20:06:07	20:06:22	lateral step		80	1500	off	off	1060
40	16040	20:06:56	20:07:13	lateral doublet		80	1500	off	off	1040
41	16041	20:07:57	20:08:10	lateral step	1k plate	80	1500	off	off	1020
42	16042	20:08:36	20:08:54	lateral doublet		80	1500	off	off	1010

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 161 **Date of Flight:** 30-Sep-96

Remarks: 80kts lat, lon, yaw, coll sweeps with 4k block load
25 HC sensor signals (no x-y acclr'rs, radar h, static P, alfa, beta)

Flight Personnel:

Pilot: G. Tucler Co-Pilot: M. Dearing
Crew Chief: J. Phillips Aircrew:

Weather:

calm **Temperature** 66 deg F
29.88 18.9 deg C

Aircraft Configuration:

ref gross weight	14601	lbs
ref x-moment	5307900	ft-lbs
ref cg station	363.6	in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 HZ

Record Number	Trends Counter	Record Times Start	Record Times Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1 thru 11	16101-11	20:21:20	20:28:45	control throws			on ground	1 on	off	
12	16112	21:06:49	21:07:20	trim	4k block	0	OGE	1,2 on	off	1980
13	16113	21:10:15	21:10:53	trim		80	1000	1,2 on	off	1920
14	16114	21:12:42	21:14:30	lateral sweep		80	1000	1,2 on	off	1890
15	16115	21:15:42	21:17:25	lateral sweep		80	1000	1,2 on	off	1850
16	16116	21:19:24	21:20:58	lateral sweep	4k block	80	1000	1,2 on	off	1810
17	16117	21:22:09	21:25:54	lateral sweep		80	1000	1,2 on	off	1760
18	16118	21:25:40	21:25:54	lateral step		80	1000	1,2 on	off	1740
19	16119	21:26:41	21:26:56	lateral doublet		80	1000	1,2 on	off	1710
20	16120	21:27:37	21:27:48	lateral step		80	1000	1,2 on	off	1700
21	16121	21:28:41	21:28:54	lateral doublet	4k block	80	1000	1,2 on	off	1680
22	16122	21:30:15	21:31:58	pedal sweep		80	1000	1,2 on	off	1660
24	16124	21:34:08	21:35:57	pedal sweep		80	1000	1,2 on	off	1620
25	16125	21:37:14	21:38:50	pedal sweep		80	1000	1,2 on	off	1580
26	16126	21:38:48	21:40:04	pedal step	4k block	80	1000	1,2 on	off	1550
27	16127	21:41:21	21:41:34	pedal step		80	1000	1,2 on	off	1530
28	16128	21:42:38	21:42:50	pedal doublet		80	1000	1,2 on	off	1520
29	16129	21:43:32	21:43:44	pedal doublet		80	1000	1,2 on	off	1500
30	16130	21:45:42	21:45:51	coll step		80	1000	1,2 on	off	1460

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Trends Counter	Record Times Start	Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
31	16131	21:46:47	21:46:59	coll doublet	4k block	80	1000	1,2 on	off	1450
32	16132	21:47:16	21:47:28	coll step		80	1000	1,2 on	off	1450
33	16133	21:48:16	21:48:29	coll doublet		80	1000	1,2 on	off	1440
34	16134	21:50:15	21:51:52	coll sweep		80	1000	1,2 on	off	1400
35	16135	21:53:39	21:55:08	coll sweep		80	1000	1,2 on	off	1360
36	16136	21:56:59	21:58:48	coll sweep	4k block	80	1000	1,2 on	off	1330
37	16137	22:00:11	22:02:03	long'l sweep		80	1000	1,2 on	off	1280
38	16138	22:04:19	22:06:01	long'l sweep		80	1000	1,2 on	off	1230
39	16139	22:07:31	22:09:18	long'l sweep		80	1000	1,2 on	off	1200
40	16140	22:10:10	22:10:15	long'l step		80	1000	1,2 on	off	1160
41	16141	22:11:00	22:11:18	long'l doublet	4k block	80	1000	1,2 on	off	1140
42	16142	22:12:33	22:12:46	long'l step		80	1000	1,2 on	off	1120
43	16143	22:13:30	12:13:50	long'l doublet		80	1000	1,2 on	off	1110
44-55	16144-55	22:28:33	22:35:43	control throws			on ground	1 on	off	

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TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 162 **Date of Flight:** 16-Oct-96
Remarks: envelop clearance for empty CONEX: trims at 0,10,...,60kts

Flight Personnel:
Pilot: R. Simmons
Co-Pilot: W. Hindson
Crew Chief: J. Phillips
Aircrew:

Weather:
Winds: 10kts @ 310 deg
Altimeter Setting (in Hg): 30.1
Temperature 66 deg F
18.9 deg C

Aircraft Configuration:

ref gross weight 14601 lbs
ref x-moment 5307900 ft-lbs
ref cg station 363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
12	16212	20:28:51	20:29:00	control throw			on ground	1 on	off	
14	16214	20:43:32	20:43:56	trim	2K CNX	hover	OGE	1,2 on	on	2180
15	16215	20:48:45	20:49:07	trim	2K CNX	30	1000	1,2 on	on	2100
16	16216	20:50:02	20:50:35	trim	2k CNX	40	1000	1,2 on	on	2090
17	16217	20:51:10	20:51:34	trim	2k CNX	50	1000	1,2 on	on	2080
18	16218	20:52:08	20:52:31	right turn	2k CNX	40	1000	1,2 on	on	2060
19	16219	20:53:36	20:54:18	trim	2k CNX	60	1000	1,2 on	on	2050
20	16220	21:01:54	21:02:28	left turn	2k CNX	40	1000	1,2 on	on	1940
21	16221	21:08:14	21:08:31	trim	2k CNX	hover	OGE	1,2 on	on	1860

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 164 **Date of Flight:** 29-Oct-96

Remarks: 40kt lat sweep with empty CONEX load
first active load instrumention

Flight Personnel:

Pilot: G. Tucker
Crew Chief: J. Phillips
Co-Pilot: unknown
Aircrew:

Weather:

Winds: not recorded
Altimeter Setting (in Hg): not recorded
Temperature not recorded

Aircraft Configuration:

ref gross weight	14601 lbs
ref x-moment	5307900 ft-lbs
ref cg station	363.6 in

Load Weights (lbs)

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counters	Record Times start	Record Times stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
4	16404	22:42:59	22:45:01	lateral sweep	2K CNX	40		1,2 ON	OFF	

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 167 **Date of Flight:** 28-Jul-97
Remarks: hover lat/lon sweeps w 2k CONEX
compass cal: initial bias = 274.6 deg

Flight Personnel:
Pilot: R. Simmons Co-Pilot: C. Sullivan
Crew Chief: J. Phillips Aircrew:

Weather:
Winds: calm **Temperature** 66 deg F
Altimeter Setting (in Hg): 29.93 18.9 deg C

Aircraft Configuration:

ref gross weight	14601 lbs
ref x-moment	5307900 ft-lbs
ref cg station	363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Times Start	Record Times Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1 thru 12	16701-12	16:08:13	16:15:15	control throws			on ground	1 on	off	hdg = 17
13	16713	16:40:32	16:40:45	trim	2k CNX	hover	130	1,2 on	off	*2075
14	16714	16:44:10	16:46:02	long'l sweep		hover	130	1,2 on	off	2030
15	16715	16:51:33	16:53:18	long'l sweep		hover	130	1,2 on	off	1950
16	16716	16:54:42	16:56:22	long'l sweep	2k CNX	hover	130	1,2 on	off	*1880
17	16717	16:57:11	16:57:26	long'l step		hover	130	1,2 on	off	*1870
18	16718	16:57:58	16:58:15	long'l step		hover	130	1,2 on	off	*1860
19	16719	16:58:57	16:59:14	long'l doublet		hover	130	1,2 on	off	*1850
20	16720	16:59:34	16:59:49	long'l doublet		hover	130	1,2 on	off	1840
21	16721	17:05:56	17:06:16	trim	2k CNX	hover	130	1,2 on	off	1730
22	16722	17:06:45	17:08:30	lateral sweep		hover	130	1,2 on	off	1700
23	16723	17:09:29	17:11:20	lateral sweep		hover	130	1,2 on	off	1660
24	16724	17:12:13	17:13:59	lateral sweep		hover	130	1,2 on	off	1600
25	16725	17:14:49	17:15:08	lateral step		hover	130	1,2 on	off	1580
26	16726	17:15:31	17:15:55	lateral step	2k CNX	hover	130	1,2 on	off	1580
27	16727	17:16:23	17:16:40	lateral doublet		hover	130	1,2 on	off	*1570
28	16728	17:16:57	17:17:13	lateral doublet		hover	130	1,2 on	off	1550
29	16729	17:17:57	17:18:09	trim		hover	130	1,2 on	off	1540
30	16730	17:18:42	17:09:02	coll doublet		hover	130	1,2 on	off	*1530

* = est'd

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 168 **Date of Flight:** 29-Jul-97

Remarks: hover lat/lon freq sweeps, 4k CONEX
compass cal: initial bias = 291.6 deg

Flight Personnel:

Pilot: R. Simmons
Co-Pilot: C. Sullivan
Crew Chief: J. Phillips
Aircrew:

Weather:

Winds: calm
Altimeter Setting (in Hg): 29.97
Temperature 61 deg F
16.1 deg C

Aircraft Configuration:

ref gross weight 14601 lbs
ref x-moment 5307900 ft-lbs
ref cg station 363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Times Start	Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1 thru 11	16801-11	14:53:10	14:59:54	control throws			on ground	1 on	off	hdg = 7deg
12	16812	15:09:47	15:10:00	Bad Record						*2360
13	16813	15:19:37	15:19:56	trim	4k CNX	hover	115	1,2 on	off	2200
14	16814	15:20:19	15:21:59	long'l sweep		hover	115	1,2 on	off	2130
15	16815	15:23:21	15:24:54	long'l sweep		hover	115	1,2 on	off	2090
16	16816	15:27:04	15:27:13	Bad Record		hover				*2030
17	16817	15:33:13	15:35:01	long'l sweep	4k CNX	hover	115	1,2 on	off	1920
18	16818	15:35:57	15:37:45	long'l sweep		hover	115	1,2 on	off	1850
19	16819	15:38:20	15:38:40	long'l step		hover	115	1,2 on	off	1810
20	16820	15:38:50	15:39:17	long'l step		hover	115	1,2 on	off	1800
21	16821	15:39:56	15:40:18	long'l doublet	4k CNX	hover	115	1,2 on	off	1780
22	16822	15:40:46	15:41:10	long'l doublet		hover	115	1,2 on	off	1760
23	16823	15:41:55	15:42:12	trim		hover	115	1,2 on	off	1750
24	16824	15:42:36	15:44:17	lateral sweep		hover	115	1,2 on	off	1720
25	16825	15:44:39	15:46:20	lateral sweep		hover	115	1,2 on	off	1680
26	16826	15:46:54	15:48:44	lateral sweep	4k CNX	hover	115	1,2 on	off	1650
27	16827	15:49:14	15:49:35	lateal step		hover	115	1,2 on	off	1610
28	16828	15:49:56	15:50:18	lateral step		hover	115	1,2 on	off	1600
29	16829	15:50:45	15:51:04	lateral doublet		hover	115	1,2 on	off	1580
30	16830	15:51:48	15:51:53	Bad Record		hover				*1565

* = est'd

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
31	16831	15:52:06	15:52:27	roll doublet	4k CNX	hover	115	1,2 on	off	1550
32	16832	15:53:10	15:53:24	trim		hover	115	1,2 on	off	1530
33	16833	15:53:53	15:54:16	coll doublet		hover	115	1,2 on	off	1510
34	16834	15:54:54	15:55:15	coll doublet		hover	115	1,2 on	off	1500
35	16835	15:58:31	15:58:59	pedal doublet		hover	115	1,2 on	off	1420

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 169 **Date of Flight:** 6-Aug-97

Remarks: hover lat sweep, 30kt lon sweeps w 4K CONEX
swiveled hook
compass cal: initial bias = 348.1 deg

Flight Personnel:

Pilot: R. Simmons Co-Pilot: C. Sullivan
Crew Chief: J. Phillips Aircrew:

Weather:

Winds: calm **Temperature** 61 deg F
Altimeter Setting (in Hg): 29.97 16.1 deg C

Aircraft Configuration:

ref gross weight	14601	lbs
ref x-moment	5307900	ft-lbs
ref cg station	363.6	in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Times start	Record Times stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1 thru 11	16901-11			control throws			on ground			hdg = 5deg
12	16912	15:33:40	15:34:00	trim	4K CNX	hover	120	1,2 on	off	*2040
13	16913	15:34:14	15:36:02	lateral sweep	4K CNX	hover	120	1,2 on	off	2030
14	16914	15:36:48	15:38:36	lateral sweep	4K CNX	hover	120	1,2 on	off	2000
15	16915	16:02:45	16:02:58	trim	4K CNX	30	500	1,2 on	off	11530
16	16916	16:03:20	16:05:04	long'l sweep	4K CNX	30	500	1,2 on	off	1500
17	16917	16:05:20	16:06:45	long'l sweep	4K CNX	30	500	1,2 on	off	*1470
18	16918	16:08:20	16:10:09	long'l sweep	4K CNX	30	500	1,2 on	off	1420
										* = est'd

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 170 **Date of Flight:** 7-Aug-97

Remarks: no load. Lat, lon sweeps at {0, 30, 50} kts
stabilator fixed full down at 30kts, 21 deg at 50kts
compass cal: initial bias = 30.8 deg

Flight Personnel:

Pilot: C. Sullivan Co-Pilot: R. Simmons

Crew Chief: Aircrew:

Weather:

Winds: 6 kts @ 240deg **Temperature** 73 deg F

Altimeter Setting (in Hg): 29.87 22.8 deg C

Aircraft Configuration:

ref gross weight 14401 lbs
ref x-moment 5251500 ft-lbs
ref cg station 364.7 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1 thru 11	17001-11	17:01:38	17:10:25	control throws			on ground	1 on	off	hdg = 320
12	17012	17:23:57	17:24:09	trim	none	hover	OGE	1,2 on	off	2240
14	17014	17:25:28	17:27:08	long'l sweep		hover	OGE	1,2 on	off	2200
15	17015	17:28:03	17:29:45	long'l sweep		hover	OGE	1,2 on	off	2170
16	17016	17:30:46	17:32:23	long'l sweep	none	hover	OGE	1.2 on	off	2120
17	17017	17:33:25	17:33:50	long'l step		hover	OGE	1,2 on	off	2100
19	17019	17:35:20	17:35:40	long'l step		hover	OGE	1,2 on	off	2070
20	17020	17:36:21	17:36:35	long'l doublet		hover	OGE	1,2 on	off	2050
21	17021	17:27:08	17:37:25	long'l doublet	none	hover	OGE	1,2 on	off	2050
22	17022	17:39:50	17:40:07	trim		hover	OGE	1,2 on	off	2000
26	17026	17:42:06	17:43:41	lateral sweep		hover	OGE	1,2 on	off	1950
27	17027	17:44:18	17:45:45	lateral sweep		hover	OGE	1,2 on	off	1910
28	17028	17:47:15	17:48:46	lateral sweep	none	hover	OGE	1,2 on	off	1880
29	17029	17:49:44	17:49:57	lateral step		hover	OGE	1,2 on	off	1850
30	17030	17:50:23	17:50:36	lateral step		hover	OGE	1,2 on	off	1850
31	17031	17:51:20	17:51:34	lateral doublet		hover	OGE	1,2 on	off	1830
32	17032	17:52:00	17:52:16	lateral doublet		hover	OGE	1,2 on	off	1810

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 172 **Date of Flight:** 20-Aug-97

Remarks: 4k CONEX load. Lat, lon sweeps at {0, 30, 50} kts
stabilator fixed 25 deg TED at 50kts
compass cal: initial bias = 269.2deg, drift = 5.1 deg/hr

Flight Personnel:

Pilot: C. Sullivan Co-Pilot: M. Dearing

Crew Chief: J. Phillips Aircrew:

Weather:

Winds: calm **Temperature** 66 deg F

Altimeter Setting (in Hg): 30.08 18.9 deg C

Aircraft Configuration:

ref gross weight	14601 lbs
ref x-moment	5307900 ft-lbs
ref cg station	363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	17201	15:39:54	15:40:20	compass cal			on ground	off	off	(HDG - 011)
11	17211	16:16:51	16:17:08	trim	4k CNX	hover	120	1,2 on	off	2150
12	17212	16:17:45	16:19:38	lateral sweep		hover	120	1.2 on	off	2140
13	17213	16:20:38	16:22:34	lateral sweep		hover	120	1,2 on	off	2080
14	17214	16:23:22	16:25:04	lateral sweep	4k CNX	hover	120	1,2 on	off	1990
15	17215	16:34:20	16:36:28	accel to 60kts		0 - 60	1000	1,2 on	off	1810
16	17216	16:38:05	16:38:21	trim		30	1000	1,2 on	off	1750
17	17217	16:41:34	16:43:20	long'l sweep		30	1000	1,2 on	off	1700
19	17219	16:46:45	16:48:41	long'l sweep	4k CNX	30	1000	1,2 on	off	1630
20	17220	16:50:15	16:51:39	long'l sweep		30	1000	1,2 on	off	1570
21	17221	16:52:37	16:52:58	long'l step		30	1000	1,2 on	off	1550
22	17222	16:54:30	16:55:00	long'l step		30	1000	1,2 on	off	1510
23	17223	16:55:05	16:56:28	long'l doublet		30	1000	1,2 on	off	1500
24	17224	16:57:10	16:57:54	long'l doublet	4k CNX	30	1000	1,2 on	off	1490
25	17225	16:59:24	16:59:39	trim		30	1000	1,2 on	off	1450
26	17226	17:02:49	17:04:40	lateral sweep		30	1000	1,2 on	off	1390
27	17227	17:05:40	17:07:24	lateral sweep		30	1000	1,2 on	off	1360
28	17228	17:08:39	17:10:37	lateral sweep		30	1000	1,2 on	off	1320

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
29	17229	17:11:35	17:11:59	lateral step	4k CNX	30	1000	1,2 on	off	1310
30	17230	17:12:48	17:13:08	lateral step		30	1000	1,2 on	off	1250
31	17231	17:13:46	17:14:07	lateral doublet		30	1000	1,2 on	off	1250
32	17232	17:17:01	17:17:19	trim		30	1000	1,2 on	off	*1220
33	17233	17:17:50	17:18:16	lateral step		30	1000	1,2 on	off	1200
34	17234	17:18:56	17:19:20	lateral doublet	4k CNX	30	1000	1,2 on	off	1180
35	17235	17:21:24	17:21:42	trim		50	1000	1,2 on	off	1150
36	17236	17:22:45	17:24:31	long'l sweep		50	1000	1,2 on	off	1130
37	17237	17:25:29	17:27:07	long'l sweep		50	1000	1,2 on	off	1090
38	17238	17:28:30	17:30:07	long'l sweep		50	1000	1,2 on	off	1040
39	17239	17:31:34	17:31:56	long'l step	4k CNX	50	1000	1,2 on	off	1010
40	17240	17:32:30	17:32:55	long'l step		50	1000	1,2 on	off	1000
43	17243	17:38:39	18:38:55	trim	4k CNX	50	1000	1,2 on	off	990
44	17244	17:39:51	17:41:11	short lat swp	4k CNX	50	1000	1.2 on	off	*930
45	17245	17:42:46	17:44:54	lateral sweep		50	1000	1,2 on	off	830
46	17246	17:45:56	17:48:05	lateral sweep		50	1000	1,2 on	off	810
47	17247	17:49:05	17:51:00	lateral sweep		50	1000	1,2 on	off	780
48	17248	17:51:30	17:51:55	lateral step		50	1000	1,2 on	off	760
49	17249	17:52:24	17:52:43	lateral step	4k CNX	50	1000	1,2 on	off	750
50	17250	17:53:10	17:53:38	lateral doublet		50	1000	1,2 on	off	710
51	17251	17:54:42	17:55:04	lateral doublet		50	1000	1,2 on	off	780
52	17252	18:04:20	18:04:36	compass cal			on ground	off	off	(HDG - 320)
										* = est'd

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 173 **Date of Flight:** 21-Aug-97

Remarks: 4k CONEX load. Lat,lon sweeps at {0, 60, 70} kts
stabilator free @ 60kts, fixed 14 deg TED @70kts
compass cal: initial heading bias = 250.0deg, drift = 16.1 deg/hr

Flight Personnel:

Pilot: C. Sullivan — Co-Pilot: M. Dearing

Crew Chief: J. Phillips — Aircrew:

Weather:

Winds: calm — **Temperature** 70 deg F

Altimeter Setting (in Hg): 30.1 — 21.1 deg C

Aircraft Configuration:

ref gross weight	14601 lbs
ref x-moment	5307900 ft-lbs
ref cg station	363.6 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	17301	16:04:30	16:04:40	compass cal			on ground	off	off	(HDG - 045)
11	17311	16:33:10	16:33:27	trim	4k CNX	hover	120	1,2 on	off	2170
12	17312	16:34:17	16:36:01	long'l sweep		hover	120	1,2 on	off	*2140
13	17313	16:36:52	16:38:39	long'l sweep		hover	120	1,2 on	off	*2070
14	17314	16:39:40	16:41:17	long'l sweep	4k CNX	hover	120	1,2 on	off	*2000
15	17315	16:46:46	16:52:44	accel to 80kts		0 - 80	1000	1,2 on	off	1830
16	17316	16:54:20	16:54:40	trim		80	1000	1,2 on	off	*1790
17	17317	16:57:52	16:58:08	trim		60	1000	1,2 on	off	1760
18	17318	16:58:37	17:00:20	long'l sweep		60	1000	1,2 on	off	1740
19	17319	17:02:30	17:04:10	long'l sweep	4k CNX	60	1000	1,2 on	off	1680
20	17320	17:05:46	17:07:36	long'l sweep		60	1000	1,2 on	off	1640
21	17321	17:12:43	17:13:04	long'l step		60	1000	1,2 on	off	1550
22	17322	17:13:52	17:14:15	long'l step		60	1000	1,2 on	off	1530
23	17323	17:14:54	17:15:17	long'l doublet		60	1000	1,2 on	off	1520
24	17324	17:15:59	17:16:24	long'l doublet	4k CNX	60	1000	1,2 on	off	1510
25	17325	17:17:25	17:17:42	trim		60	1000	1,2 on	off	1500
26	17326	17:20:12	17:21:56	lateral sweep		60	1000	1,2 on	off	1440
27	17327	17:22:48	17:24:30	lateral sweep		60	1000	1,2 on	off	1420
28	17328	17:26:26	17:28:13	lateral sweep		60	1000	1,2 on	off	1360

* = est'd

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
29	17329	17:30:20	17:30:45	lateral step	4k CNX	60	1000	1,2 on	off	1320
30	17330	17:31:30	17:31:59	lateral step		60	1000	1,2 on	off	1290
31	17331	17:32:32	17:03:00	lateral doublet		60	1000	1,2 on	off	1290
32	17332	17:33:37	17:34:07	lateral doublet		60	1000	1,2 on	off	1270
33	17333	17:39:50	17:40:12	trim		70	1000	1,2 on	off	1180
34	17334	17:41:49	17:43:29	trim	4k CNX	70	1000	1,2 on	off	1140
36	17336	17:50:36	17:52:25	long'l sweep		70	1000	1,2 on	off	980
37	17337	17:54:23	17:56:01	long'l sweep		70	1000	1,2 on	off	940
38	17338	17:56:26	17:57:00	aborted lon swp		70	1000	1,2 on	off	*890
39	17339	18:07:05	18:07:23	long'l step	4k CNX	70	1000	1,2 on	off	810
40	17340	18:08:10	18:08:30	long'l doublet		70	1000	1,2 on	off	800
41	17341	18:09:29	18:09:40	trim		70	1000	1,2 on	off	760
42	17342	18:10:09	18:10:10	aborted lat swp		70	1000	1,2 on	off	710
45	17345	18:13:54	18:15:37	lateral sweep	4k CNX	70	1000	1,2 on	off	700
46	17346	18:16:05	18:17:45	lateral sweep		70	1000	1,2 on	off	680
47	17347	18:19:00	18:20:43	lateral sweep		70	1000	1,2 on	off	650
48	17348	18:21:08	18:21:32	lateral step		70	1000	1,2 on	off	*615
49	17349	18:21:50	18:22:12	lateral doublet		70	1000	1,2 on	off	570
50	17350	18:31:56	18:32:10	compass cal	none		on ground	off	off	(HDG - 315)

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 177 **Date of Flight:** 28-Jan-99
Remarks: 4K block load
short sweeps, SAS not calibrated

Flight Personnel:
Pilot: M. Dearing Co-Pilot: C. Sullivan
Crew Chief: F. Matulac Aircrew: Z Szoboszlay

Weather:
Winds: 11kts@330deg **Temperature** 12degC
Altimeter Setting (in Hg): 30.31

Aircraft Configuration:

ref gross wt:	14689 lbs
ref X moment:	5313200 ft-lbs
ref cg station:	361.7 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	3895
6k Block	5995
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
2	17702	22:40:38	22:41:39	trim	4K block	hvr	OGE	on	off	1550
3	17703	22:47:36	22:48:59	long'l sweep		hvr	OGE	on	off	1430
4	17704	22:59:38	23:00:56	long'l sweep		hvr	OGE	on	off	1260
5	17705	23:01:53	23:03:12	long'l sweep		hvr	OGE	on	off	1220
6	17706	23:04:09	23:04:23	long'l doublet		hvr	OGE	on	off	1180
7	17707	23:05:26	23:05:55	long'l doublet	4K block	hvr	OGE	on	off	1150
8	17708	23:06:32	23:08:04	lateral sweep		hvr	OGE	on	off	1130
9	17709	23:09:33	23:11:09	lateral sweep		hvr	OGE	on	off	1080
10	17710	23:12:16	23:13:45	lateral sweep		hvr	OGE	on	off	1020
11	17711	23:14:37	23:14:58	lateral doublet		hvr	OGE	on	off	990
12	17712	23:15:31	23:16:03	lateral doublet	4K block	hvr	OGE	on	off	970
14	17714	23:18:03	23:18:37	coll doublet		hvr	OGE	on	off	930
15	17715	23:23:52	23:24:32	trim		30kts	1000	on	off	830
16	17716	23:26:09	23:27:46	long'l sweep		30kts	1000	on	off	810
17	17717	23:29:01	23:30:42	long'l sweep	4K block	30kts	1000	on	off	770

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 178 **Date of Flight:** 29-Jan-99

Remarks: 4K block load

recs 12-24, 29 - no mixers, SAS, boom, radalt channels

Flight Personnel:

Pilot: M. Dearing Co-Pilot: C. Sullivan

Crew Chief: F. Matulac Aircrew: Zoltan Szoboszlay

Weather:

Winds: calm **Temperature (° F):** 6 deg C

Altimeter Setting (in Hg): 30.28 inHg

Aircraft Configuration:

ref gross wt: 14689 lbs

ref X moment: 5313200 ft-lbs

ref cg: 361.7 in

Load Weights (lbs):

Load	Weight
No Load	0
1k Plate	1070
4k Block	3895
6k Block	5995
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	17801	10:13:48	10;15:34	lon sweep	4K block	30	1000	on	off	2190
2	17802	10:17:17	10:17:46	lon doublet	4K block	30	1000	on	off	2140
4	17804	10:20:11	10:20:41	lon doublet	4K block	30	1000	on	off	*2100
5	17805	10:21:24	10:23:03	lat swp (shrt)	4K block	30	1000	on	off	2080
7	17807	10:27:03	10:29:26	lat sweep	4K block	30	1000	on	off	2010
8	17808	10:30:55	10:32:46	lat sweep	4K block	30	1000	on	off	1970
9	17809	10:33:35	10:34:05	lat doublet	4K block	30	1000	on	off	1920
10	17810	10:34:46	10:35:14	lat doublet	4K block	30	1000	on	off	1900
11	17811	10:36:24	10:36:56	coll doublet	4K block	30	1000	on	off	1880
12	17812	10:37:31	10:38:03	coll doublet	4K block	30	1000	on	off	1860
13	17813	10:39:18	10:39:57	trim	4K block	50	1000	on	off	1830
14	17814	10:41:08	10:42:41	lon sweep	4K block	50	1000	on	off	1820
15	17815	10:44:40	10:46:16	lon sweep	4K block	50	1000	on	off	1770
16	17816	10:47:47	10:49:20	lon sweep	4K block	50	1000	on	off	1730
17	17817	10:51:38	10:52:08	lon doublet	4K block	50	1000	on	off	1680
19	17819	11:03:20	11:03:55	lon doublet	4K block	50	1000	on	off	1520
20	17820	11:04:26	11:06:11	lat sweep	4K block	50	1000	on	off	1510

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Filename	Record Time		Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
		Start	Stop							
21	17821	11:07:46	11:09:23	lat sweep	4k block	50	1000	on	off	1480
22	17822	11:11:17	11:12:31	aborted sweep	4k block	50	1000	on	off	1430
24	17824	11:17:13	11:19:31	lat sweep	4k block	50	1000	on	off	*1355
25	17825	11:22:06	11:24:20	lat sweep	4k block	50	1000	on	off	1290
26	17826	11:24:47	11:25:32	lat doublet	4k block	50	1000	on	off	1280
27	17827	11:26:01	11:36:41	lat doublet	4k block	50	1000	on	off	1240
28	17828	11:33:41	11:35:51	lon sweep	4k block	hover	OGE	on	off	1140
29	17829	11:36:20	11:37:50	lon sweep	4k block	hover	OGE	on	off	1100
31	17831	11:39:27	11:41:12	lon sweep	4k block	hover	OGE	on	off	1020
										* = est'd

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 179 **Date of Flight:** 12-Feb-99
Remarks: 4K CONEX, swiveled sling

Flight Personnel:

Pilot: M. Dearing Co-Pilot: C. Sullivan
Crew Chief: F. Matulac Aircrew: Z. Szoboszlay

Weather:

Winds: calm **Temperature** 7degC
Altimeter Setting (in Hg): 30.3

Aircraft Configuration:

ref gross wt: 14689 lbs
ref X moment: 5313200 ft-lbs
ref cg: 361.7 in

Load Weights (lbs):

Load	Weight
No Load	0
1k Plate	1070
4k Block	3895
6k Block	5995
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 HZ

Record Number	Filename	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
4	17904	17:15:20	17:17:23	lon sweep	4K CNX	hover	OGE	1,2 on	off	2030
5	17905	17:18:20	17:20:05	lon sweep		hover	OGE	on	off	1980
6	17906	17:20:44	17:21:18	lon doublet		hover	OGE	on	off	1920
7	17907	17:21:47	17:22:19	lon doublet	4K CNX	hover	OGE	on	off	1900
8	17908	17:23:09	17:25:07	lat sweep		hover	OGE	on	off	1870
9	17909	17:25:50	17:27:45	lat sweep		hover	OGE	on	off	1820
10	17910	17:28:53	17:30:39	lat sweep		hover	OGE	on	off	1770
11	17911	17:31:11	17:31:42	lat doublet		hover	OGE	on	off	1720
12	17912	17:32:21	17:32:54	lat doublet	4K CNX	hover	OGE	on	off	1700
13	17913	17:33:33	17:34:09	coll doublet		hover	OGE	on	off	1680
14	17914	17:34:33	17:35:10	coll doublet		hover	OGE	on	off	1660
15	17915	17:40:22	17:41:06	trim		30	1000	on	off	1560
16	17916	17:43:10	17:45:16	lon sweep	4K CNX	30	1000	on	off	1520
17	17917	17:46:35	17:48:57	lon sweep		30	1000	on	off	1470
18	17918	17:49:24	17:51:23	lon sweep		30	1000	on	off	1430
19	17919	17:52:05	17:52:52	lon doublet		30	1000	on	off	1400
20	17920	17:53:44	17:54:32	lon doublet		30	1000	on	off	1370

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Filename	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
21	17921	17:56:20	17:58:20	lat sweep	4K CNX	30	1000	on	off	1330
22	17922	17:58:59	18:00:59	lat sweep		30	1000	on	off	1300

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 180 **Date of Flight:** 12-Feb-99

Remarks: 4K block load
uncalibrated SAS

Flight Personnel:

Pilot: C Sullivan
Co-Pilot: M Dearing
Crew Chief: F. Matulac
Aircrew: Z Szoboszlay

Weather:

Winds: calm
Temperature 13degC
Altimeter Setting (in Hg): 30.22

Aircraft Configuration:

ref gross wt: 14689 lbs
ref X moment: 5313200 ft-lbs
ref cg: 361.7 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
2	18001	21:36:57	21:37:37	trim	4K block	hover	OGE	1,2 on	off	2230
3	18002	21:37:53	21:39:55	lon swp (short)	4K block	hover	OGE	1,2on	off	*2200
4	18003	21:40:26	21:42:33	lon sweep	4K block	hover	OGE	1,2on	off	2160
6	18006	21:44:35	21:46:49	lon sweep	4K block	hover	OGE	1,2 on	off	2090
7	18007	21:47:23	21:47:47	lon doublet	4K block	hover	OGE	1,2on	off	2031
8	18008	21:48:09	21:48:42	lon doublet	4K block	hover	OGE	1,2on	off	2010
9	18009	21:49:05	21:49:30	lon doublet	4K block	hover	OGE	1,2on	off	1990
10	18010	21:54:40	21:57:01	lon sweep	4K block	50	1000	1,2on	off	1900
11	18011	21:57:48	21:59:48	lon sweep	4K block	50	1000	1,2 on	off	*1850
12	18012	22:01:00	22:05:59	lon sweep	4K block	50	1000	1,2on	off	1820
13	18013	22:03:16	22:05:16	lon sweep	4K block	50	1000	1,2on	off	1780
14	18014	22:05:47	22:06:18	lon doublet	4K block	50	1000	1,2on	off	1750
15	18015	22:06:40	22:07:14	lon doublet	4K block	50	1000	1,2on	off	1740
16	18016	22:08:57	22:11:05	lat sweep	4K block	50	1000	1,2 on	off	1720
17	18017	22:12:59	22:14:50	lat sweep	4K block	50	1000	1,2on	off	1660
18	18018	22:15:19	22:17:20	lat sweep	4K block	50	1000	1,2on	off	1630
19	18019	22:18:36	22:19:05	lat doublet	4K block	50	1000	1,2on	off	1600
20	18020	22:19:31	22:20:07	lat doublet	4K block	50	1000	1,2on	off	1580

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 181 **Date of Flight:** 25-Mar-99
Remarks: 6K block load. Load weight high (6450) due to water in the block

Flight Personnel:
Pilot: M. Dearing Co-Pilot: G. Tucker
Crew Chief: F. Matulac Aircrew: Z Szoboszlay

Weather:
Winds: calm **Temperature** 16+degC
Altimeter Setting (in Hg): 29.87

Aircraft Configuration:

ref gross wt:	14689	lbs
ref X moment:	5313200	ft-lbs
ref cg:	361.7	in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4205
6k Block	6450
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	18101	17:56:45	17:58:18	trim	6K block	hover	OGE	on	off	960
2	18102	17:59:44	18:01:44	long'l sweep		hover	OGE	on	off	880
3	18103	18:02:39	18:04:33	long'l sweep		hover	OGE	on	off	830
4	18104	18:05:23	18:07:16	long'l sweep		hover	OGE	on	off	760
5	18105	18:08:23	18:09:10	long'l doublet		hover	OGE	on	off	710
6	18106	18:10:10	18:10:41	long'l doublet	6K block	hover	OGE	on	off	670
7	18107	18:11:39	18:13:15	lateral sweep		hover	OGE	on	off	630
8	18108	18:14:04	18:16:13	lateral sweep		hover	OGE	on	off	620
9	18109	18:17:10	18:19:12	lateral sweep		hover	OGE	on	off	550
10	18110	18:20:08	18:21:00	lateral doublet		hover	OGE	on	off	480
11	18111	18:21:28	18:21:59	lateral doublet	6K block	hover	OGE	on	off	470
refuel										
12	118112	19:24:41	19:25:11	trim		30	1000	on	off	1370
13	18113	19:27:12	19:29:11	long'l sweep		30	1000	on	off	1330
14	18114	19:30:57	19:32:32	long'l sweep		30	1000	on	off	1250
15	18115	19:33:59	19:35:31	long'l sweep	6K block	30	1000	on	off	1230
16	18116	19:36:30	19:37:10	long'l doublet		30	1000	on	off	1200
17	18117	19:37:35	19:38:08	long'l doublet		30	1000	on	off	1180
18	18118	19:39:17	19:40:59	lateral sweep		30	1000	on	off	1160
19	18119	19:41:29	19:43:05	lateral sweep		30	1000	on	off	1130

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Trends Counter	Record Time		Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
		Start	Stop							
20	18120	19:44:38	19:46:17	lateral sweep	6K block	30	1000	on	off	1090
21	18121	19:48:23	19:49:00	lateral doublet		30	1000	on	off	1030
22	18122	19:49:32	19:50:03	lateral doublet		30	1000	on	off	1020
23	18123	19:51:16	19:51:45	trim		50	1000	on	off	990
24	18124	19:52:15	19:53:43	long'l sweep	6K block	50	1000	on	off	980
25	18125	19:55:26	19:57:08	long'l sweep		50	1000	on	off	940
26	18126	19:58:07	19:59:38	long'l sweep		50	1000	on	off	890
27	18127	20:00:15	20:00:50	long'l doublet		50	1000	on	off	870
28	18128	20:01:22	20:01:51	long'l doublet		50	1000	on	off	850
29	18129	20:04:01	20:05:45	lateral sweep	6K block	50	1000	on	off	820
30	18130	20:07:20	20:09:09	lateral sweep		50	1000	on	off	770

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 182 **Date of Flight:** 17-May-99
Remarks: 4K lbs block load - hvr (lat), 30, 50 kts

Flight Personnel:

Pilot: G. Tucker
Co-Pilot: C. Sullivan
Crew Chief: F. Matulac
Aircrew: Z Szoboszlay

Weather:

Winds: 4kts
Temperature 13 degC
Altimeter Setting (in Hg): 30.14

Aircraft Configuration:

ref gross wt:	14689 lbs
ref X moment:	5313200 ft-lbs
ref cg:	361.7 in

Load Weights (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	18201	16:32:08	16:32:37	trim	4K block	hover	OGE	on	off	2100
2	18202	16:33:21	16:35:36	lateral sweep		hover	OGE	on	off	2080
3	18203	16:36:00	16:37:38	lateral sweep		hover	OGE	on	off	2020
4	18204	16:38:11	:16:39:50	lateral sweep		hover	OGE	on	off	1980
5	18205	16:40:28	16:42:14	lateral sweep		hover	OGE	on	off	1930
6	18206	16:42:40	16:43:13	lateral doublet	4K block	hover	OGE	on	off	1890
7	18207	16:43:31	16:44:00	lateral doublet		hover	OGE	on	off	1830
8	18208	16:48:28	16:48:53	trim		80	1000	on	off	1800
9	18209	16:49:51	16:51:52	lateral sweep		80	1000	on	off	1780
10	18210	16:52:56	16:54:57	lateral sweep		80	1000	on	off	1740
11	18211	16:56:00	16:58:33	lateral sweep	4K block	80	1000	on	off	1700
12	18212	16:59:01	16:59:37	lateral doublet		80	1000	on	off	1670
13	18213	16:59:56	17:00:27	lateral doublet		80	1000	on	off	1650
14	18214	17:01:22	17:03:15	long'l sweep		80	1000	on	off	1640
15	18215	17;04:20	17:06:20	long'l sweep		80	1000	on	off	1600
16	18216	17:06:47	17:08:30	long'l sweep	4K block	80	1000	on	off	1560
17	18217	17:09:33	17:09:54	long'l doublet		80	1000	on	off	1540
18	18218	17:10:26	17:10:59	long'l doublet		80	1000	on	off	1520
19	18219	17:11:23	17:11:47	long'l doublet		80	1000	on	off	1500

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Filename	Record Time		Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
		Start	Stop							
20	18220	17:14:50	17:15:15	trim	4K block	30	1000	on	off	1450
21	18221	17:22:40	17:24:37	lateral sweep		30	1000	on	off	1370
22	218222	17:25:03	17:26:48	lateral sweep		30	1000	on	off	1330
23	18223	17:27:44	17:29:33	lateral sweep		30	1000	on	off	1300
24	18224	17:28:56	17:30:29	lateral doublet		30	1000	on	off	1260
25	18225	17:30:52	17:31:28	lateral doublet	4K block	30	1000	on	off	1250
26	18226	17:31:57	17:33:15	long'l sweep		30	1000	on	off	1230
27	18227	17:34:56	17:36:43	long'l sweep		30	1000	on	off	1200
28	18228	17:37:06	17:38:46	long'l sweep		30	1000	on	off	1170
29	18229	17:39:30	17:40:21	long'l doublet	4K block	30	1000	on	off	1130
30	18230	17:40:54	17:41:26	long'l doublet		30	1000	on	off	1120
31	18231	17:42:13	17:42:47	long'l doublet		30	1000	on	off	1090

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Flight #: 183 **Date of Flight:** 17-May-99

Remarks: 6K block @ 6350lbs including sling. 50, 80 kts
rec 2 ended at 1Hz, recs 17-19 are poor sweeps

Flight Personnel:

Pilot: G. Tucker Co-Pilot: C. Sullivan

Crew Chief: F. Matulac Aircrew: Z Szoboszlay

Weather:

Winds: 4kts **Temperature** 16 degC

Altimeter Setting (in Hg): 30.13

Aircraft Configuration:

ref gross wt: 14689 lbs

ref X moment: 5313200 ft-lbs

ref cg: 361.7 in

Load Weigths (lbs):

No Load	0
1k Plate	1070
4k Block	4300
6k Block	6352
2k Conex	1794
4k Conex	4105

Directory Name: TRENDS BSL **Sample Rate:** 100 Hz

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
1	18301	18:42:50	18:43:37	trim	6K block	80	1000	on	off	1140
2	18302	18:44:39	18:46:38	lateral sweep		80	1000	on	off	1130
3	18302	18:47:35	18:49:19	lateral sweep		80	1000	on	off	1120
4	18304	18:49:40	18:51:24	lateral sweep		80	1000	on	off	1070
5	18305	18:52:25`	18:52:59	lateral doublet		80	1000	on	off	1030
6	18306	18:53:37	18:54:07	lateral doublet	6K block	80	1000	on	off	1020
7	18307	18:55:30	18:57:19	long'l sweep		80	1000	on	off	1000
8	18308	18:58:20	19:00:12	long'l sweep		80	1000	on	off	970
9	18309	19:01:05	19:02:49	long'l sweep		80	1000	on	off	920
10	18310	19:03:22	19;03:55	long'l doublet		80	1000	on	off	890
11	18311	19:04:48	19:05:15	long'l doublet	6K block	80	1000	on	off	870
12	18312	19:05:59	19:06:35	long'l doublet		80	1000	on	off	850
13	18313	19:08:27	19:08:50	trim		50	1000	on	off	820
14	18314	19:09:11	19:10:49	lateral sweep		50	1000	on	off	810
15	18315	19:11:24	19:13:39	lateral sweep	6K block	50	1000	on	off	790
16	18316	19:13:54	19:15:51	lateral sweep		50	1000	on	off	760

TABLE 3. CATALOG OF DATA RECORDS BY FLIGHT (CONTINUED)

Record Number	Trends Counter	Record Time Start	Record Time Stop	Maneuver	Load	Airspeed (knots)	Altitude (feet)	SAS	FPS	Fuel Wt. (pounds)
17	18317	19:16:42	19:18:24	long'l sweep	6K block	50	1000	on	off	720
18	18318	19:19:18	19:20:57	long'l sweep		50	1000	on	off	700
19	18319	19:21:17	19:22:50	long'l sweep		50	1000	on	off	650
20	18320	19:23:21	19:23:45	long'l dblet		50	1000	on	off	630
21	18321	19:24:04	19:24:28	long'l dblet		50	1000	on	off	620
22	18322	19:25:13	19:25:45	lateral dblet		50	1000	on	off	610
23	18323	19:26:05	19:26:32	lateral dblet		50	1000	on	off	590
24	18324	19:27:19	19:28:52	lateral sweep		50	1000	on	off	570
25	18325	19:29:48	19:31:20	long'l sweep		50	1000	on	off	560

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13. ABSTRACT *(Maximum 200 words)*
Helicopter slung-load operations are common in both military and civil contexts. Helicopters and loads are often qualified for these operations by means of flight tests, which can be expensive and time consuming. There is significant potential to reduce such costs both through revisions in flight-test methods and by using validated simulation models. To these ends, flight tests were conducted at Moffett Field to demonstrate the identification of key dynamic parameters during flight tests (aircraft stability margins and handling-qualities parameters, and load pendulum stability), and to accumulate a data base for simulation development and validation. The test aircraft was a UH-60A Black Hawk, and the primary test load was an instrumented 8- by 6- by 6-ft cargo container. Tests were focused on the lateral and longitudinal axes, which are the axes most affected by the load pendulum modes in the frequency range of interest for handling qualities; tests were conducted at airspeeds from hover to 80 knots. Using telemetered data, the dynamic parameters were evaluated in near real time after each test airspeed and before clearing the aircraft to the next test point. These computations were completed in under 1 min. A simulation model was implemented by integrating an advanced model of the UH-60A aerodynamics, dynamic equations for the two-body slung-load system, and load static aerodynamics obtained from wind-tunnel measurements. Comparisons with flight data for the helicopter alone and with a slung load showed good overall agreement for all parameters and test points; however, unmodeled secondary dynamic losses around 2 Hz were found in the helicopter model and they resulted in conservative stability margin estimates.

14. SUBJECT TERMS
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